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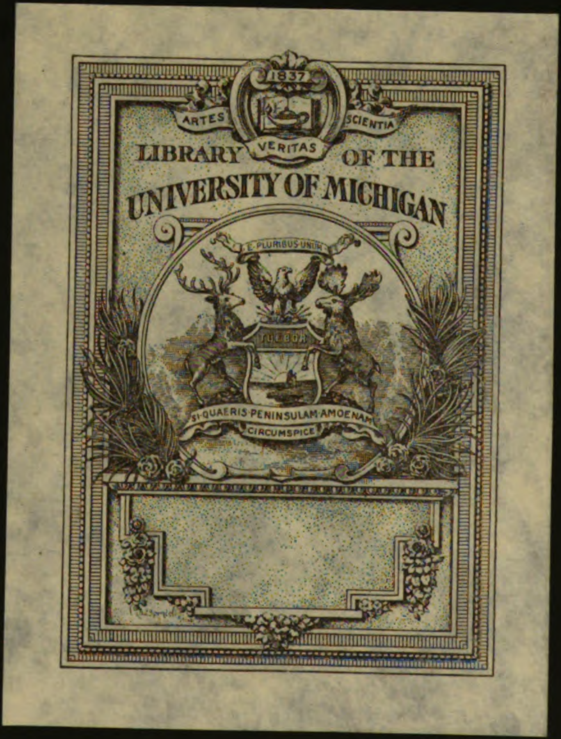
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Excursion on the Clyde.

Frontispiece.

THE JOURNAL

OF THE

IRON AND STEEL INSTITUTE.

VOL. LXXI.

EDITED BY

BENNETT H. BROUGH.

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SECRETARY

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PREFACE

THE joint meeting of the Iron and Steel Institute and the American Institute of Mining Engineers, in London on July 23rd to 28th, 1906, resulted in the presentation of so large a number of valuable papers, that it has been found impossible to compress the minutes of proceedings into one volume. The report has, therefore, been broken up into two parts, Nos. III. and IV., the numbering of the pages being continuous, with one index at the end of this part.

Part No. III. contains the addresses by Mr. R. A. Hadfield, President of the Iron and Steel Institute, and by Captain R. W. Hunt, President of the American Institute of Mining Engineers, and the papers presented to both Institutes read at the meeting, together with some of the papers presented to the Iron and Steel Institute taken as read.

This part contains the remainder of the papers presented to the Iron and Steel Institute taken as read, namely, those by Professor Sauveur and by Mr. Thomas, and certain important papers presented to the American Institute of Mining Engineers, and under a friendly agreement between the Councils of the two Institutes, available for publication by this Institute. The latter, which include papers by Messrs. Aldrich, Baker, Corson, Hibbard, McCaustland, and White, have for lack of space been necessarily published in abstract. This part also contains reports of the reception by H.M. the King, of the

161791

Annual Dinner, and of the visits and excursions. It also contains a report of the proceedings of the International Testing Congress, obituary notices of deceased members, library reports, and the usual notes on the progress of the home and foreign iron and steel industries during the second half of 1906.

28 VICTORIA STREET, LONDON,
December 31, 1906.

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THE CONSTITUTION OF IRON-CARBON ALLOYS.

BY ALBERT SAUVEUR (CAMBRIDGE, MASS., U.S.A.).

IT is not without some hesitation, and even misgiving, that I venture into a discussion of the now classical Roberts-Austen Roozeboom diagram, lest I too fail, like so many other writers, in giving a satisfactory and logical explanation of these interesting curves.

Roozeboom's original diagram is reproduced in Fig. 1. The generally accepted meaning of the various curves has been so often described before this Institute that it will suffice to recall it briefly before passing to my own interpretation of the changes involved.

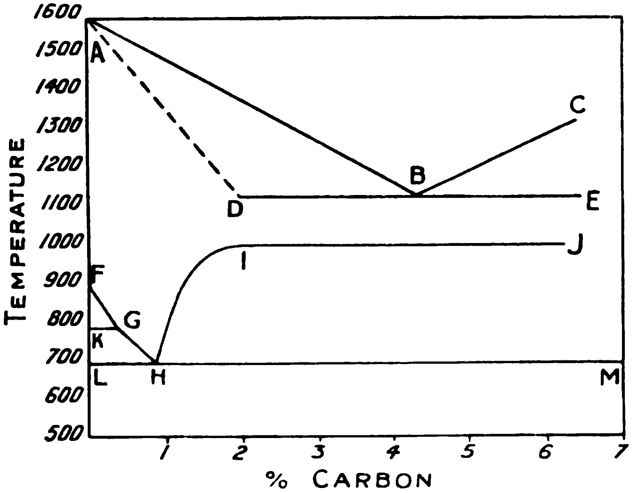

FIG. 1.

In Fig. 2 I have divided the diagram into three parts by dotted lines, and I have designated them I., II., and III. respectively.

In part I. is shown the fusibility curve of iron-carbon alloys containing from zero to 2 per cent. of carbon, and seeing that it consists of a straight line, or at least a smooth curve, drawn between the melting point of pure iron and that of iron containing 2 per cent. of carbon, it may at once be inferred (from a knowledge of the meaning of such curves in general) that alloys of iron and carbon up to 2 per cent. of carbon form a solid solution when they pass from the liquid to the solid state, which means, as Professor Howe has well stated, that the merging between the carbon and the iron remains complete and in indefinite proportions — the essential characteristics of solution. Were we, however, to follow this analogy further we could logically infer that the two constituents of this solid solution must be: (1) iron free from carbon, and (2) iron containing 2 per cent. of carbon, and that the latter constituent is dissolved in the former. If this be so, we would at once ask what is the nature of that constituent which contains 2 per cent. of carbon. Is it a carbide of iron which is thus dissolved in the iron? I am well aware that this is not the generally accepted conception of the nature of the solid solution, it being assumed that it is the carbon itself which is dissolved and not a carbide of iron. It should be borne in mind, however, that this view is somewhat opposed by the analogy offered by

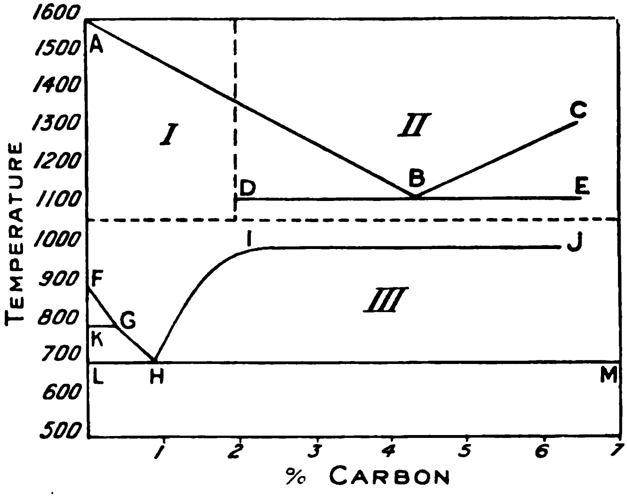

FIG. 2.

alloys in general, and while in further discussing the diagram I shall refer to the solid solution as a solution of carbon in iron, it will be with the reservation that, to my mind, it has never been shown conclusively that it was carbon rather than a carbide which was dissolved by the iron, and that the latter inference may be the more logical one.

It may be recalled also that the position of the point D (Fig. 1) has not been positively ascertained, and this should be remembered when we assume that 2 per cent. represents the maximum amount of carbon in the solid solution.

Furthermore, since it is generally accepted that iron at a high temperature exists in a certain allotropic condition known as γ-iron, we must infer that this solid solution is a solution of carbon (or of a carbide) in γ-iron.

It is for this solid solution that Osmond has proposed the name of "austenite," and there should not be any room for misunderstanding or confusion regarding the meaning of that term. This austenite remains stable until the lower critical points, soon to be described, are reached. Let it also be borne in mind that the proportion of carbon in austenite necessarily increases gradually from zero to 2 per cent., according to the carbon-content of the alloy, and that it should be expected that the properties of austenite will likewise vary.

Passing now to the zone marked II., we have here the fusibility curve of iron-carbon alloys containing more than 2 per cent. of carbon. The diagram at once suggests the typical fusibility curve of alloys forming neither solid solutions nor definite compounds, and, therefore, forming a eutectic alloy. Its meaning is clear. Two constituents form upon solidification: (1) graphite, and (2) a solid solution of carbon in iron containing 2 per cent. of carbon, which, for simplicity of speech, may be designated "2 per cent. austenite," while the meeting point of the two curves indicates the formation of a eutectic alloy (graphite + 2 per cent. austenite eutectic), which contains about 4·3 per cent. of carbon. The constitution after solidification of these highly carburised alloys can then be readily inferred. If the metal contains from 2 to 4·3 per cent. of carbon, it will be made up of (1) what may be termed "excess" austenite, and (2) graphite-austenite eutectic the former constituent decreasing in quantity, and the latter increasing as the carbon-content in the alloy increases. If the alloy contains over 4·3 per cent. of carbon, it will consist of (1) excess graphite, and (2) graphite-austenite eutectic, the former increasing and the latter decreasing in quantity with the carbon-content in the alloy.

In Fig. 3 I have attempted to show graphically in the diagram itself the composition of iron-carbon alloys, after solidification, in percentages of the constituents. The scheme adopted has now been used by several writers, and will, I believe, be readily understood. In the lower part of the diagram a similar graphical representation is given of the constituents of fully cooled alloys soon to be described.

From previous knowledge of the laws governing the solidifying of metallic alloys in general it has thus been found possible to account, in an apparently satisfactory manner, for the constitution of iron-carbon alloys immediately after their solidification, and there is much in the evidence presented, and in the unmistakable character of the curves, to impart confidence that the essential features of these inferences at least rest on sound foundation.

Passing to the zone marked III. in Fig. 2, it is here that my opinion differs from that of most previous writers regarding the meanings to be ascribed to the curves in this zone. Let us bear in mind that we are now dealing with a solid metal, so that the evolution of heat noted on cooling is no longer connected with the phenomenon of solidification. There is no further change of state, and these evolutions, which indicate a change of internal energy, must apparently be ascribed either to the formation of chemical compounds or to some allotropic changes. It is well to remember that after the alloy has solidified, and whatever its carbon-content, it can contain only two constituents: (1) graphite, and (2) solid solution or austenite (the eutectic present being merely a mechanical mixture of these two components), and that whatever changes are to take place on further cooling must mean a change in the nature of one or both of these two constituents. If we now examine the curves in this zone III. we see that they again recall strikingly the typical fusibility curves of alloys forming neither solid solutions nor definite compounds, and

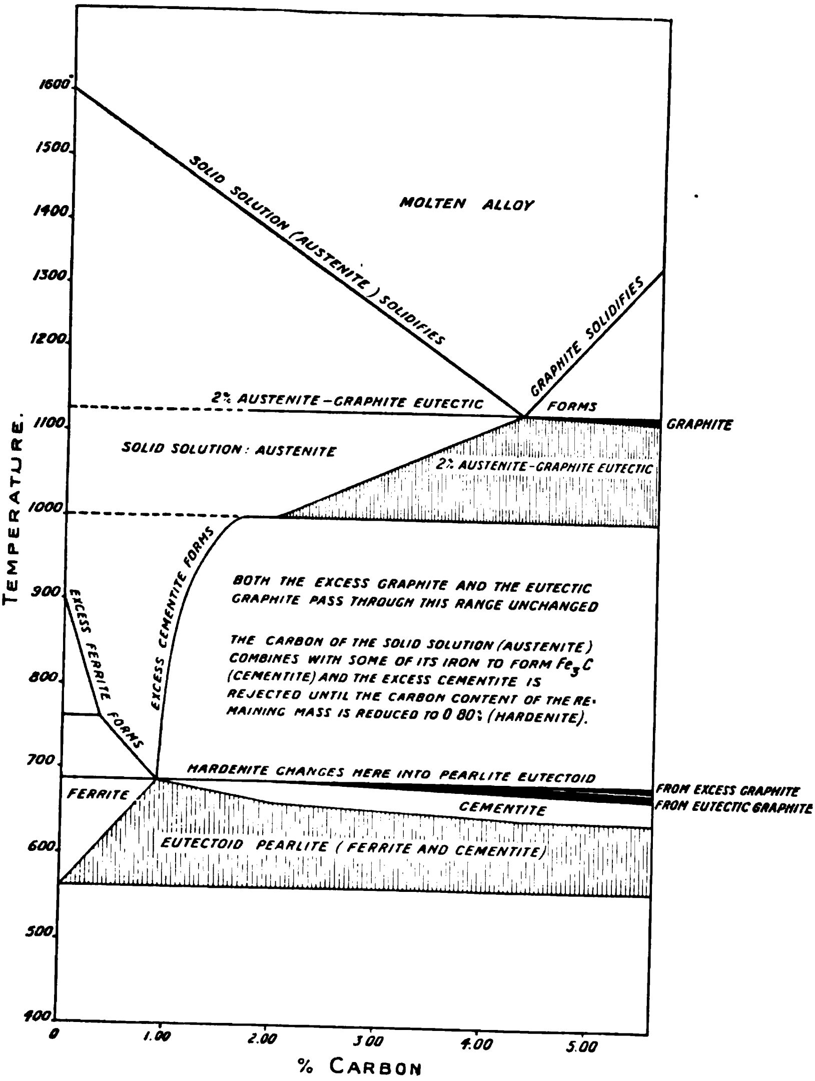

FIG. 3.

giving rise, therefore, to a eutectic alloy. That a eutectic-like alloy is formed when a solid iron-carbon alloy cools through a certain critical range is known beyond any possible doubt. The two components of that alloy are: (1) iron free from carbon, and (2) a carbide of iron containing 6·67 per cent. carbon, or, to use the metallographical terms, ferrite and cementite, the alloy itself being called pearlite. It follows from this that the two upper branches—namely, FGH and HIJ—must correspond respectively to the formation of the excess ferrite and excess cementite. This leads us to the natural conclusion that the solid solution austenite, which exists at a high temperature, upon further cooling, and at some definite critical temperature, breaks up into ferrite and pearlite, or into cementite and pearlite, according to the carbon-content, or, in other words, that the excess ferrite or the excess cementite falls out of, or segregates from, this solid solution very much like the excess metal falls out of, or crystallises from, a liquid solution upon reaching the freezing point of that solution. While there is great analogy between these phenomena, however, there is also a momentous difference in the fact that the formation of pearlite does not imply a change of state. Pearlite is not the alloy of lowest melting point, which is the meaning of "eutectic." This is why Professor Howe has proposed the very happy term "eutectoid" for this eutectic-like constituent, and this term should certainly be generally adopted.

That the final constituents of iron-carbon alloys are produced by this breaking up of the solid solution austenite is admitted by all writers, provided the carbon does not exceed 2 per cent.

With a higher carbon-percentage, however—that is to say, when graphite begins to make its appearance on solidifying—it has generally been contended that this graphite plays a part in the further transformation of the alloy. It has been argued that when the line IJ (Fig. 2) is reached, cementite is here produced not only from the breaking up of the austenite, but also from the graphite actually combining with some of the iron of the austenite to form the carbide Fe_3C. According to these views there is no room for graphite below that line. When graphite is found in an iron-carbon alloy it is assumed that it is due to "lag," by which it is meant that because of molecular inertia and the absence of favourable conditions, such as slow cooling, &c., graphite has been prevented from being converted into cementite. According to this view it is held that all cast irons, free from silicon and other disturbing elements, must normally be white—that is to say, free from graphitic carbon. When they are grey—that is, when they contain graphitic carbon—their constitution is, so to speak, abnormal, the metal having failed to assume a stable condition.

It seems to me that a careful study of the curves, and still more of the structure of samples after suitable treatments utterly fails to support this contention, and, indeed, that it points to exactly the opposite conclusion—namely, that the graphite which forms during solidification plays no part in the further transformation of the alloys, and that it merely acts as an inert substance passing through the critical range unaffected. The formation of graphite in the absence of impurities depends solely upon (1) the total amount of carbon in the alloy, and (2) the rate of cooling through the solidification range. Once formed, I believe that this graphite cannot be made to combine with iron. An alloy containing more than 2 per cent. carbon consists, after solidification, as it has been shown, of a mass of solid solution containing many particles or grains of graphite distributed through it, which, for the purpose of illustration, may be compared to a molten mass of some metallic alloy mixed, let us say, with pebbles. Upon cooling and solidifying, the expected changes will take place in the alloy proper, but the pebbles will take no part in it.

In accordance with this conception, I have given in the appendix, and indicated graphically in Fig. 3, what should be the theoretical composition of iron-carbon alloys in percentages of the constituents, and after slow cooling from the melting point, and I think that it will be found to agree closely with the structure observed in various grades of steel and cast iron free from impurities (and especially from silicon and sulphur) and allowed to cool slowly from the molten condition. To ascribe an active part to the graphite in the changes occurring at the critical points is further opposed by our knowledge of the nature and behaviour of graphite, for it is well known that once formed no kind of heat treatment has ever resulted in producing any change in its nature.

Let us look a little more closely into the evidences brought forward in support of the contention that the graphite formed during solidification combines on further cooling and at a certain definite temperature with some of the iron to form the carbide Fe_3C.

So far as I am aware this assumption rests chiefly, (1) upon the presence of the curve IJ in the diagram (see Fig. 2), and (2) upon the application of the phase rule to iron-carbon alloys. These may be considered in the order given.

I. *Evidences Based upon the Presence of the Curve IJ* (Fig. 2).—While there is very good reason to suppose that the line IJ indicates the formation of cementite in the cooling alloy, its existence does not even remotely suggest that this cementite is produced by the combination of graphite with iron. Indeed, it seems to me, that all indications point strongly the other way, notwithstanding Roozeboom's opinion that the line IJ "Can have no other meaning than that at 1000° there is in the normal state of stable equilibrium an abrupt transformation of the graphite into carbide (cementite)." *

Let it be considered that the curve IJ is the continuation of the curve HI, and that the intervention of graphite is not needed to explain the meaning of HI. We know that the curve HI indicates the formation of cementite from the solid solution austenite, and it may well be asked what is the justification for abruptly and profoundly modifying the meaning of that curve the moment the carbon-content exceeds 2 per cent., or, in other words, as soon as graphite appears on solidification. It is illogical to ascribe a certain meaning to the portion HI of the curve HIJ, and another meaning to the portion IJ. How can this be defended? Is there not, on the contrary, every reason to suppose that the meaning of the portion IJ is identical with that of HI—namely, that it indicates the segregation of cementite from the solid solution austenite, a phenomenon in which the graphite which happens to be present in highly carburised alloys plays no part. To sum up, it seems to me that the presence of the line IJ in the diagram, instead of indicating an active intervention of the graphite, suggests strongly, by analogy, that, like the portion HI of the same curve, it indicates the formation of excess cementite within the austenite.

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* "Iron and Steel from the Point of View of the 'Phase Doctrine.'" *Journal of the Iron and Steel Institute*, 1900, No. II. p. 311.

II. *Evidences Based on the Phase Rule.*—We are told that according to the phase rule only two phases can exist in a state of stable equilibrium in iron-carbon alloys, and that, therefore, if graphite be present, besides ferrite and cementite, (pearlite not being a phase, but merely a mechanical mixture of the two phases, ferrite and cementite), it must be due to "lag"; that is, because the conditions prevailing during the cooling were not favourable to the production of stable equilibrium. According to this view the graphite which forms normally during solidification must disappear on further cooling, *i.e.* must be converted into cementite by combination with some iron, when passing through the curve IJ (Fig. 2).

When iron-carbon alloys solidify they must of course do so in accordance with the phase rule, and after solidification can only contain two phases—namely, graphite and austenite; but once solidified they are converted into a mechanical mixture of these two constituents, and their further transformation can no longer be governed by the phase rule, for that rule is not applicable to mechanical mixtures as such.

To be sure since one of the constituents of that mixture happens to be a solid solution the further transformations of that constituent, of course, should take place according to the phase rule, and it should not, after final cooling, contain more than two phases; but the alloy as a whole, being a mechanical mixture, is no longer under that rule, so that finally we should have, in a state of stable equilibrium, (1) graphite formed on solidifying, and which remains inert during further cooling, and (2) ferrite and cementite from the transformation of the solid solution, and in accordance with the phase rule.

Here again I would compare the iron-carbon alloy after solidification to a molten alloy containing pebbles. While the further transformation of the molten alloy itself must take place in accordance with the phase rule, the pebbles will take no part in it, and will be found in the solidified mass.

Having reviewed the arguments advanced in favour of the transformations of graphite into cementite, I shall briefly indicate the evidence supporting the view brought forward in this paper, that of the non-intervention of graphite in any change taking place below solidification.

1. The existence of the curve, HIJ (Fig. 2), instead of suggesting a transformation of the graphite along the portion IJ, strongly suggests that, by analogy, IJ must mean, like HJ, the rejection of excess cementite from the solid solution (austenite).

2. The well-known behaviour of graphite which resists transformation by any known heat treatment short of melting is opposed to the theory.

3. The results of a few experiments which will now be briefly described appear to show conclusively that Roozeboom's theory is untenable.

Some electrolytic iron, produced by Professor Charles F. Burgess of the University of Wisconsin, and kindly supplied by him, was melted in a graphite crucible brasqued with magnesia, together with an excess of sugar charcoal in a gas crucible furnace.

The composition of the electrolytic iron was as follows:—

	Analysis by Professor Burgess.	Author's Analysis.
Carbon	...	none
Silicon	none	none
Phosphorus . . .	0·018 per cent.	0·013 per cent.
Sulphur . . .	0·003 ,,	trace
Manganese . . .	...	none

After melting, the crucible and its contents were allowed to cool very slowly in the furnace. It will be noted that these conditions were exceptionally favourable to the production of a pure iron-carbon alloy in a state of stable equilibrium, they being practically free from the disturbing influence of impurities, and the "lag," so far as due to too rapid cooling at least, being minimised. Absence of impurities and extremely slow cooling should at least promote stable equilibrium; that is, those conditions should promote the transformation which theoretically are assumed to take place at the various thermal critical points. Admitting the necessary interference of "lag," notwithstanding our conditions and magnifying its importance to the utmost, we should certainly still expect, if Roozeboom's theory be true, the resulting alloy to contain relatively little graphite, certainly less than the amount normally formed during solidification. In other words, under the favourable conditions indicated surely some of the graphite should be converted into cementite. If no such conversion whatever takes place, and if it be still maintained that the theory is nevertheless correct, it assumes a purely speculative and unacceptable character. If, on the contrary, the opposite view be true, the amount of graphite after slow cooling should not be less than the amount formed during the solidification period, and which can be readily calculated (see appendix) from the percentage of total carbon.

It was found that the iron-carbon alloy produced in this experiment contained 4·354 per cent. total carbon. This amount of carbon should yield during solidification 2·40 per cent. graphite (see appendix), while the analysis of the alloy showed 3·066 per cent. graphite. Not only did any graphite fail to combine with iron at the critical temperature of 1000°, but some of the cementite actually broke up into carbon (temper carbon) and iron during the very slow cooling from this temperature. It will be readily seen that the conditions were such as to cause a certain amount of "malleablising."

The amount of silicon in this alloy was found to be 0·028 per cent.

A photomicrograph of this alloy is shown in Fig. 4.

Let us emphasise the meaning of the formation of this large amount of graphite during solidification in the practical absence of silicon and the retention of that graphite in its entirety during slow cooling, and let us oppose this result to such assertions, as that of Ledebur, that in order to produce graphite during solidification "a second element beside carbon must be present,"* as that of Roozeboom, that the curve IJ (Fig. 2) can have no other meaning than that of the disappearance of graphite,* and as that of Howe that graphite in highly carburised iron free from silicon can only be present by "lag." †

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* *Handbuch der Eisenhüttenkunde*, Leipzig, 1903, p. 310.

While in view of the conclusive nature of the results of the experiment just recorded it did not seem necessary to carry the argument further, other experiments, however, were conducted with a view of bringing about this alleged combination of the graphite, but in every case it was found impossible to reduce the amount of graphite formed during solidification. It will suffice to describe here two of the most significant of these additional tests.

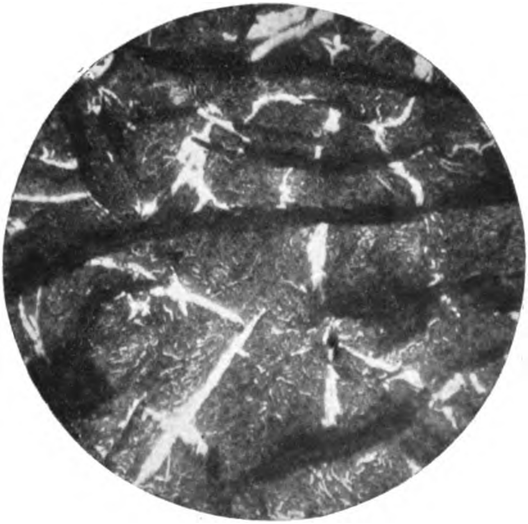

FIG. 4.—Electrolytic iron melted with excess carbon and allowed to solidify and cooled very slowly. Magnified 100 diameters.

A piece of the iron-carbon alloy produced in the first experiment was reheated to 1000° C. (the temperature indicated by I J, Fig. 2), and kept at that temperature for five hours. According to the Roozeboom theory we might reasonably expect that some, if only a very little, of the graphite would be converted into cementite, but the amount of total carbon was found to be 2·87 per cent. and the graphitic carbon 1·928 per cent. The theoretical amount of graphite which should form on solidification with a total carbon-content of 2·87 should be 0·89 per cent. It is seen that instead of additional cementite forming, as Roozeboom's theory would have it, a large amount of that constituent was decomposed and 1·038 per cent. temper carbon formed, by keeping the metal at the critical temperature of 1000° (claimed to be a cementite forming temperature) and cooling slowly therefrom. The microstructure of this iron is shown in Fig. 5.

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* "Iron and Steel from the Point of View of the 'Phase Doctrine.'" *Journal of the Iron and Steel Institute*, 1900, No. II. p. 311.

† "Iron, Steel, and Other Alloys," Boston, 1903, p. 195 and *seq.*

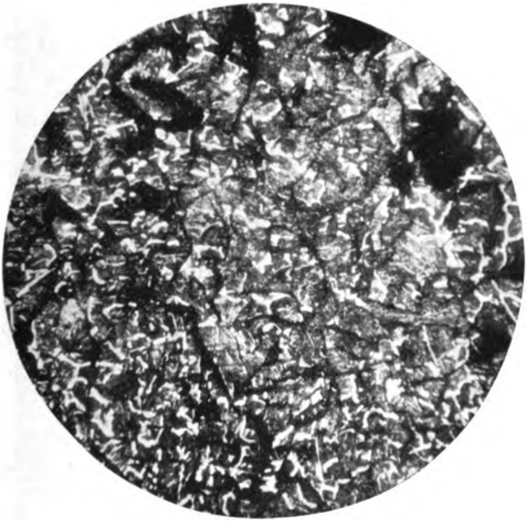

Fig. 5.—Same alloy as that shown in Fig. 4, but reheated to 1000° C. for five hours and very slowly cooled. Magnified 100 diameters.

Another alloy with excess carbon was melted exactly as in the first experiment and allowed to solidify slowly in the furnace until its temperature was 1100° C., when the crucible and contents were quickly transferred to a muffle furnace previously heated to 1000° C., and maintained at that temperature for five hours. More favourable conditions for the disappearance of graphite, according to Roozeboom's theory, cannot readily be conceived, but it was found that the alloy contained 3·63 per cent. total carbon and 2·74 per cent. graphitic carbon, while the amount of graphite which should form theoretically during solidification is 1·63 per cent. (see appendix). Here again, therefore, the graphitic carbon failed to combine with iron, while a considerable amount of temper carbon was produced. The structure of this alloy is shown in Fig. 6. It was found to contain 0·031 per cent. silicon. These results are given below in a tabular form.

Treatment.	Analysis. Per Cent.		Theoretical per Cent. of Graphite formed during Solidification.	Temper Carbon formed at and below 1000° C.
*1. Electrolytic iron, melted with excess carbon and very slowly cooled	Total carbon	4·354	2·40	0·666
	Graphitic carbon	3·066		
	Combined carbon	1·288		
*2. Same as No. 1, but reheated to 1000° C. for 5 hours and slowly cooled	Total carbon	2·870	0·89	1·038
	Graphitic carbon	1·928		
	Combined carbon	0·942		
*3. Electrolytic iron, melted with excess carbon, allowed to solidify slowly, kept 5 hours at 1000° C., and cooled slowly	Total carbon	3·630	1·63	0·544
	Graphitic carbon	2·174		
	Combined carbon	1·456		

These repeated failures to induce any of the graphite to combine with iron under the most favourable conditions that could be devised appear to be conclusive evidences that the graphite which forms during the slow solidification of highly carburised iron takes no part in any further transformation, and is to be found in the cooled alloy not by "lag" but by right.

It is hardly necessary here to explain why commercial cast irons are produced which contain a great deal more graphite than the theoretical amount, and indeed in which cementite may be altogether absent, while others contain much less graphite than the theoretical amount, and may even be free

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* These carbon determinations were made by Booth, Garrett, and Blair of Philadelphia.

from that constituent. The former variety owe their constitution chiefly to the presence of silicon, which during solidification promotes the formation of an excess graphite above the theoretical amount, while the latter variety shows a deficit or even a complete absence of graphite chiefly because of too rapid a solidification, and frequently also because of the presence of sulphur, or of some other interfering element opposing the formation of graphite. In order to obtain the theoretical amount of graphite two conditions are essential: (1) very slow cooling during solidification, and (2) absence of disturbing foreign elements, and these conditions are not realised in commercial cast iron. If the silicon, sulphur, and other impurities be removed from cast iron and the alloy be then allowed to solidify very slowly, the theoretical amount of graphite will be produced and retained whether the iron was originally grey, mottled, or white.

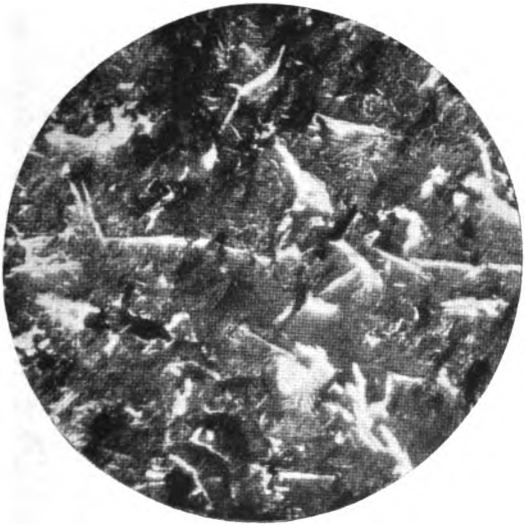

FIG. 6.—Electrolytic iron melted with excess carbon, allowed to solidify slowly, kept five hours at 1000° C and slowly cooled. Magnified 100 diameters.

Before bringing this argument to a close a few words should be said regarding the production of malleable cast-iron castings, and which, as is well known, results from long annealing of white cast-iron castings at a temperature generally not far from 1000° C., or precisely the temperature indicated by the curve IJ (Fig. 2), where formation of cementite, and not of graphite, should be induced according to Roozeboom's theory. Strangely enough, however, the advocates of that theory seem to find in the results of this operation an argument in support of their view. When white cast iron is heated to 1000° C., why should any graphitic or "temper" carbon be formed? Is it not opposed to Roozeboom's theory? Is not white cast iron at 1000° C. in a state of stable equilibrium, seeing that all its carbon is combined as it should be according to that theory? How then can this spontaneous transformation of a stable into an unstable equilibrium (formation of graphitic carbon) be explained?

On the contrary, if the view be accepted that graphite should be normally formed and retained on slow cooling, we are led to look upon white cast iron as being in a state of unstable equilibrium, and it can readily be understood how by single reheating, even much below the melting point, a certain return to that state must take place, which means the formation of a certain amount of graphitic, or, as it is often called, "temper" carbon. This behaviour of white cast iron is very similar to that of hardened steel subjected to tempering. Both white cast iron and hardened steel are in an unstable condition, the former because of too rapid cooling through the solidification period, the latter because of too rapid cooling through the critical range (700° C. or thereabouts). Both metals have a latent tendency to assume a more stable condition, which means the formation of cement carbon in hardened steel and the formation of graphitic carbon in white cast iron, and both metals will show a partial return at least to a more stable condition if they be heated to a temperature which may be considerably below the critical point through which the metal was cooled too quickly—namely, below 700° C. for hardened steel, and below the solidification temperature in the case of white cast iron. These facts are summarised in the following table:—

	Unstable because of too Rapid Cooling through.	Result of too Rapid Cooling.	Restored Partially or Wholly to Stable Condition.	Result of Reheating.
Hardened steel	Critical range.	Formation of cement carbon prevented.	By reheating below critical range.	Formation of cement carbon.
White cast iron	Solidification range.	Formation of graphitic carbon prevented.	By reheating below solification range.	Formation of graphite or "temper" carbon.

The weight of evidence appears to me strongly to point to white cast iron being in an unstable condition, the formation of graphite having been prevented through too sudden cooling or because of the presence of disturbing elements. The stable alloy should contain the normal amount of graphite formed on solidification, and reheating to a relatively low temperature will permit a partial or complete return of the metal to its stable condition, hence the possible conversion of white cast iron into malleable, graphitic iron by annealing.

AUSTENITE, MARTENSITE, TROOSTITE, AND PEARLITE.

In Fig. 7 I have drawn, on a large scale, the thermal curves of iron-carbon alloys resulting from the evolutions of heat which take place spontaneously long after the metal has solidified. This diagram is an attempt to give a graphical representation of the following well-known and generally accepted facts:—

(1) The point Ar3 in carbonless iron and in low carbon alloys corresponds to the passage of the iron from the allotropic condition γ to the allotropic condition β, and also to the separation of some excess ferrite, which must necessarily be β-ferrite.

(2) The point Ar2 in carbonless and low carbon alloys corresponds to the passage of the iron from the allotropic condition β to the allotropic condition a and probably to the

separation of an additional amount of excess ferrite which must necessarily be α-ferrite.

(3) The point Ar1 in low, medium, and high carbon alloys is due to the formation of the carbide Fe_3C or cementite.

(4) The point Ar3,2 of medium high carbon alloys implies that the Ar3 and Ar2 changes just described occur at, or nearly at, the same temperature, the γ-iron passing to β-iron and immediately after to α-iron, while the excess ferrite separates.

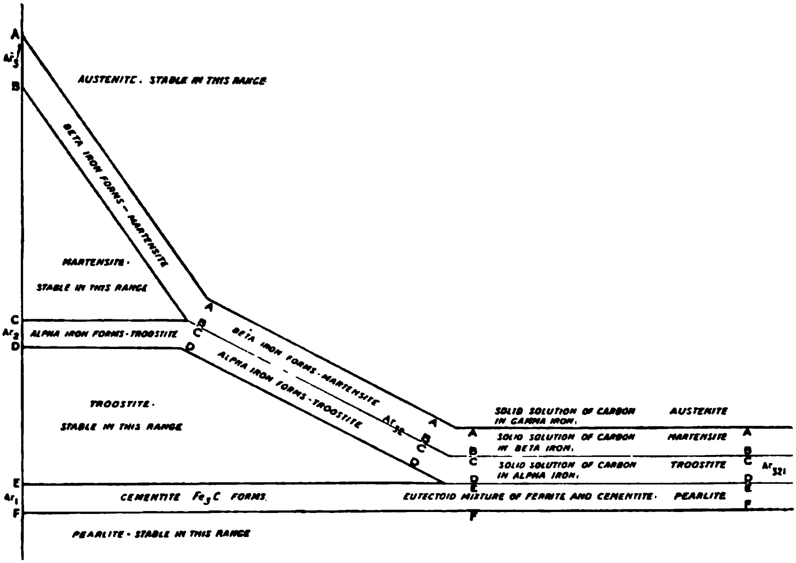
A
Ar_3
B
AUSTENITE. STABLE IN THIS RANGE
BETA IRON FORMS - MARTENSITE
MARTENSITE.
STABLE IN THIS RANGE
C
Ar_2
D
ALPHA IRON FORMS - TROOSTITE
A
B
C
D
BETA IRON FORMS - MARTENSITE
ALPHA IRON FORMS - TROOSTITE
Ar_{32}
TROOSTITE.
STABLE IN THIS RANGE
SOLID SOLUTION OF CARBON IN GAMMA IRON.
AUSTENITE
SOLID SOLUTION OF CARBON IN BETA IRON.
MARTENSITE
SOLID SOLUTION OF CARBON IN ALPHA IRON.
TROOSTITE
Ar_{321}
E
Ar_1
F
CEMENTITE Fe_3C FORMS.
EUTECTOID MIXTURE OF FERRITE AND CEMENTITE.
PEARLITE
PEARLITE. STABLE IN THIS RANGE

FIG. 7.

(5) The point Ar3,2,1 of high carbon steel implies that the changes Ar3, Ar2, and Ar1 now occur at, or nearly at, the same temperature, the γ-iron passing to β, then immediately to α, while the carbide Fe_3C forms, which compound must necessarily be a carbide of α-iron.

Before discussing at greater length the meaning of these curves I desire to state emphatically that I am not propounding here any new theory, especially as to the nature of troostite, but merely inquiring into the meaning of the changes taking place at the thermal critical points.

The inferences to be drawn from this diagram may possibly be made clearer by a series of questions which it suggests.

Is it not evident that the two allotropic changes which take place at Ar3,2 do not occur simultaneously but successively? Must not the γ-iron first pass to the β state before assuming the a condition? This is clearly indicated in the diagram.

Is it not likewise evident that the three changes which occur at Ar3,2,1 do not take place simultaneously but successively? Does not this critical point involve three distinct and successive transformations, (1) the passage of γ-iron to β-iron, (2) the passage of β-iron to a-iron, and (3) the formation of the carbide Fe_3C? This interpretation of the single point Ar3,2,1 is also clearly shown graphically in the diagram.

After cooling through AB—that is, through Ar3 or through the upper zone of Ar3,2 or of Ar3,2,1—does not the iron-carbon alloy consist of a solid solution of carbon in β-iron (mixed, in the case of low carbon steel, with some free β-ferrite), and does not this condition remain stable, through the range BC, which range is, of course, reduced to a line in the case of the points Ar3,2 and Ar3,2,1?

Is not martensite the proper name for this solid solution of carbon in β-iron and which must be necessarily formed at some temperature, whatever the carbon-content of the alloy, and which is also the first transformation of austenite, that is, of the solid solution of carbon in γ-iron? Is not this in perfect agreement with Osmond's description of these two constituents, and should there remain any more doubt or confusion as to their nature? Martensite is harder than austenite simply because of the fact that the β-iron which it contains is harder than γ-iron. Are not then austenite and martensite two distinct and well-defined constituents? It is of course well known that in the ordinary quenching we do not usually prevent the passage of austenite into martensite; that is, of γ- into β-iron—from which it follows that martensite and not austenite is the ordinary constituent of hardened steel, and it is also well known that the further transformation of martensite is greatly retarded by the presence of carbon, so that in a high carbon steel we are able to retain martensite much more readily than with a lower carbon-content. By the very sudden quenching of high carbon steel, it is possible to retain, as Osmond has shown, about half of the alloy in the austenite condition, the other half assuming the martensite state.

Passing now to the range CD, that is to the point Ar2, or to the lower zone of Ar3,2, or the middle zone of Ar3,2,1, does not the iron change here from the β to the α condition, and does not the alloy now consist of a solid solution of carbon in α-iron? If this be not correct we must revise our conception of the meaning of the point Ar2. And does not this solid solution of carbon in α-iron remain stable and unchanged through the range DE, which of course in high carbon steel is reduced to a single line, and is not this solid solution of carbon in α-iron the illusive and much maligned constituent troostite? Is it not logical to infer that it is troostite? Does it not correspond to the first transformation of martensite or hardenite before its final conversion into pearlite while passing through the range EF, that is through Ar1 or through the lower zone of Ar3,2,1? Does not this conception agree with the generally accepted view that troostite is a transition constituent between martensite and pearlite? Is not such conception of the nature of troostite in agreement with our knowledge of the conditions required for its formation and with its properties, and indeed is it opposed by any evidences so far brought forward? To produce troostite we must cool the alloy through the critical range slowly enough to allow its formation and rapidly enough to prevent its further transformation into pearlite, or we may obtain it by cooling suddenly from the lower zone of the critical range, that is from the temperature DE where troostite has been formed and is for the time being a stable constituent. Here again it should be borne in mind that it is not generally possible to retain all the alloy in the condition of troostite, because the formation of these transition forms does not take place simultaneously throughout the same specimen. By properly regulated cooling we shall obtain a mixture of troostite and martensite, while if the cooling be less rapid the result will be a mixture of troostite and pearlite or indeed a

PLATE LI

Structural Composition after Slow Cooling.											
Proximate Composition.			Ultimate Composition.						Total Ferrite. F+F′.	Total Cementite. C+C′.	Total Graphite. G+G′.
Excess Ferrite. F.	Excess Cementite. C.	Total Graphite. G+G′.	Eutectoid Ferrite. F′.	Excess Ferrite. F.	Eutectoid Cementite. C′.	Excess Cementite. C.	Eutectic Graphite. G′.	Excess Graphite. G.			
87·50	...	...	11·00	87·50	1·50	...	...	...	98·50	1·50	...
75·00	...	...	22·00	75·00	3·00	...	...	...	97·00	3·00	...
62·50	...	...	33·00	62·50	4·50	...	...	...	95·50	4·50	...
50·00	...	...	44·00	50·00	6·00	...	...	...	94·00	6·00	...
37·50	...	...	55·00	37·50	7·50	...	...	...	92·50	7·50	...
25·00	...	...	66·00	25·00	9·00	...	...	...	91·00	9·00	M
12·50	...	...	77·00	12·50	10·50	...	...	...	89·50	10·50	...
...	...	...	88·00	...	12·00	...	...	...	88·00	12·00	...
...	1·70	...	86·50	...	11·80	1·70	...	...	86·50	13·50	...
...	3·41	...	85·00	...	11·59	3·41	...	...	85·00	15·00	...
...	5·11	...	83·50	...	11·39	5·11	...	...	83·50	16·50	...
...	6·81	...	82·00	...	11·19	6·81	...	...	82·00	18·00	...
...	8·52	...	80·50	...	10·98	8·52	...	...	80·50	19·50	...
...	10·22	...	79·00	...	10·78	10·22	...	...	79·00	21·00	...
...	11·93	...	77·50	...	10·57	11·93	...	...	77·50	22·50	...
...	13·63	...	76·00	...	10·37	11·63	...	...	76·00	24·00	...
...	15·33	...	74·50	...	10·17	15·33	...	...	74·50	25·50	...
...	17·04	...	73·00	...	9·96	17·04	...	...	73·00	27·00	...
...	18·74	...	71·50	...	9·76	18·74	...	...	71·50	28·50	...
...	20·44	...	70·00	...	9·56	20·44	...	...	70·00	30·00	...
...	20·42	0·10	69·94	...	9·54	20·42	0·10	...	69·94	29·96	0·10
...	20·49	0·20	69·87	...	9·53	20·40	0·20	...	69·87	29·93	0·20
...	20·38	0·31	69·79	...	9·52	20·38	0·31	...	69·79	29·90	0·31
. .	20·36	0·41	69·72	...	9·51	20·36	0·41	...	69·72	29·87	0·41
...	20·34	0·51	69·65	...	9·50	20·34	0·51	...	69·65	29·84	0·51
...	20·32	0·61	69·58	...	9·49	20·32	0·61	...	69·58	29·81	0·61
...	20·30	0·71	69·51	...	9·48	20·30	0·71	...	69·51	29·78	0·71
...	20·28	0·82	69·43	...	9·47	20·28	0·82	...	69·43	29·75	0·82
...	20·25	0·92	69·37	...	9·46	20·25	0·92	...	69·37	29·71	0·92
...	20·23	1·02	69·30	...	9·45	20·23	1·02	...	69·30	29·68	1·02
...	20·21	1·12	69·23	...	9·44	20·21	1·12	...	69·23	29·65	1·12
...	20·19	1·22	69·16	...	9·43	20·19	1·22	...	69·16	29·62	1·22
...	20·17	1·32	69·09	...	9·42	20·17	1·32	...	69·09	29·59	1·32
...	20·15	1·42	69·02	...	9·41	20·15	1·42	...	69·02	29·56	1·42
...	20·13	1·52	68·95	...	9·40	20·13	1·52	...	68·95	29·53	1·52
...	20·11	1·63	68·87	...	9·39	20·11	1·63	...	68·87	29·50	1·63
...	20·09	1·73	68·80	...	9·38	20·09	1·73	...	68·80	29·47	1·73
...	20·07	1·83	68·73	...	9·37	20·07	1·83	...	68·73	29·44	1·83
...	20·04	1·94	68·66	...	9·36	20·04	1·94	...	68·66	29·40	1·94
...	20·02	2·04	68·59	...	9·35	20·02	2·04	...	68·59	29·37	2·04
...	20·00	2·14	68·52	...	9·34	20·00	2·14	...	68·52	29·34	2·14
...	19·97	2·25	68·45	...	9·33	19·97	2·25	...	68·45	29·30	2·25
...	19·96	2·35	68·37	...	9·32	19·96	2·35	...	68·37	29·28	2·35
...	19·92	2·45	68·32	...	9·31	19·92	2·35	0·10	68·32	29·23	2·45
...	19·93	2·54	68·23	...	9·30	19·93	2·34	0·20	68·23	29·23	2·54
...	19·90	2·65	68·16	...	9·29	19·90	2·34	0·31	68·16	29·19	2·65
...	19·88	2·75	68·09	...	9·28	19·88	2·34	0·41	68·09	29·16	2·74
...	19·86	2·86	68·01	...	9·27	19·86	2·34	0·52	68·01	29·13	2·86
...	19·84	2·95	67·95	...	9·26	19·84	2·33	0·62	67·95	29·10	2·95
...	19·82	3·06	67·87	...	9·25	19·82	2·33	0·73	67·87	29·07	3·06

mixture of these three constituents, while, of course, in low carbon steel some excess ferrite may also be present.

To sum up the above considerations, microscopical evidences have shown conclusively that four distinct constituents are formed through the cooling of steel, namely austenite, martensite, troostite, and pearlite, and it has also been shown that martensite, and especially troostite, may be regarded as transition constituents in the transformation of austenite into pearlite. Now, on the other hand, if we look into the meaning of the thermal critical points of steel, as illustrated in Fig. 7, we also find that four constituents must necessarily be formed during the cooling of steel, and that these must be respectively (1) solid solution of carbon in γ-iron, (2) solid solution of carbon in β-iron, (3) solid solution of carbon in α-iron, and (4) the iron-carbide eutectoid, and the conclusion that these four constituents must be those revealed by microscopical examination, that is, respectively austenite, martensite, troostite, and pearlite, appears not only reasonable, but, it seems to me, inevitable.

APPENDIX.

CALCULATIONS TO OBTAIN THE PERCENTAGES OF THE CONSTITUENTS OF IRON-CARBON ALLOYS.

THE percentages of the various constituents which should normally be present in iron-carbon alloys may be readily calculated provided the proportion of total carbon be known.

In these calculations the following notations are used :—

A = Excess Austenite.
A' = Eutectic Austenite.
G = Excess Graphite.
G' = Eutectic Graphite.
E = Graphite-Austenite Eutectic $(A' + G')$.
F = Excess Ferrite.
F' = Eutectoid Ferrite.
C = Excess Cementite.
C' = Eutectoid Cementite.
P = Pearlite or Ferrite-Cementite Eutectoid $(F' + C')$.
R = Percentage of Carbon in the alloy.

Let us consider (I.) the composition after solidification, and (II). the composition after slow cooling to atmospheric temperature or at least below the lower critical point.

I.—*Composition after Solidification.*

Three cases are to be considered: (1) the alloy contains less than 2 per cent. carbon, (2) the alloy contains between 2 and 4·3 per cent. carbon, and (3) the alloy contains more than 4·3 per cent. carbon.

1. Alloys which contain less than 2 per cent. carbon are made up after solidification exclusively of the solid solution austenite, $A = 100$ per cent.

2. Alloys containing between 2 and 4·3 per cent. carbon consist after solidification of excess austenite (A), and of a eutectic alloy (E), which in turn is a mechanical mixture of austenite (A′), and graphite (G′).

We have—

(1) $A + E = 100$, and since the excess austenite contains 2 per cent. carbon and the eutectic 4·3 per cent. carbon, we must have

$$\frac{2 \cdot 00}{100} A + \frac{4 \cdot 3}{100} E = R \tag{2}$$

in which R represents the known percentage of carbon in the alloy.

The percentage of graphite in the eutectic may likewise be readily obtained. Let A′ and G′ represent respectively the amount of austenite and of graphite in the eutectic, then

$$(a)\quad A' + G' = 100$$

and

$$(b)\quad \frac{2{\cdot}00}{100} . A' + G' = 4{\cdot}3$$

which gives $G' = 2{\cdot}35$ for the percentage of graphite in the eutectic.

Let us suppose, for instance, that the alloy contains 3·5 per cent. carbon. The above calculations will give for the, so to speak, proximate structural composition, immediately after solidification:

	Per Cent.
Excess austenite (A)	34·78
Eutectic (E)	65·22
	100·00

and for its ultimate structural composition—

	Per Cent.
Excess austenite (A)	34·78
Eutectic austenite (A′)	63·70
Eutectic graphite (G′)	1·52
	100·00

or again—

	Per Cent.
Total austenite (A + A′)	98·48
Eutectic graphite	1·52
	100·00

2. Alloys which contain more than 4·3 per cent. carbon are made up after solidification of excess graphite (G), and some eutectic (E = A′ + G′), and we have

$$(1)\quad G + E = 100$$

$$(2)\quad G + \frac{4{\cdot}3}{100} E = R$$

in which R represents the known percentage of carbon.

If the alloy contains 5 per cent. carbon, for instance, it should be composed after solidification of

	Per Cent.
Excess graphite (G)	0·73
Eutectic (E)	99·27
	100·00

and its ultimate composition will be, since the eutectic contains 2·35 per cent. carbon,

	Per Cent.
Excess graphite (G)	0·73
Eutectic graphite (G′)	2·33
Eutectic austenite (A′)	96·94
	100·00

or again

	Per Cent.
Total graphite (G+G′)	3·06
Eutectic austenite (A′)	96·94
	100·00

To test the accuracy of these figures—since the austenite contains 2 per cent. carbon, 96·94 of austenite will contain 1·94 per cent. carbon, which added to the 3·06 per cent. graphite gives 5 per cent. as the total amount of carbon in the alloy.

II.—*Composition after Slow Cooling.*

Four cases have now to be considered: (1) the alloy contains from 0 to 0·8 per cent. carbon, (2) the alloy contains from 0·8 to 2 per cent. carbon, (3) the alloy contains from 2 to 4·3 per cent. carbon, (4) it contains over 4·3 per cent. carbon.

1. If the alloy contains less than 0·8 per cent. it consists after slow cooling of some excess ferrite (F), and pearlite (P), which in turn is a mechanical mixture of ferrite and cementite (F′ + C′).

We have—

$$(1)\quad F+P=100$$

$$(2)\quad \frac{0{\cdot}80}{100}P=R$$

The percentage of ferrite and cementite in the eutectoid pearlite may readily be calculated as follows:

$$(a)\quad F'+C'=100$$

$$(b)\quad \frac{6{\cdot}67}{100}\quad =0{\cdot}80$$

which gives F′ = 88 and C′ = 12.

If the alloy, for instance, contains 0·20 per cent. carbon, then its proximate structural composition will be

	Per Cent.
Ferrite $(F)_1$	75
Pearlite $(P)_1$	25
	100

and its ultimate composition, since pearlite contains 12 per cent. cementite, will be

	Per Cent.
Excess ferrite (F)	75
Eutectoid ferrite (F′)	22
Eutectoid cementite (C′)	3
	100

or again

	Per Cent.
Total ferrite (F + F′)	97
Eutectoid cementite (C′)	3
	100

2. If the alloy contains from 0·8 to 2 per cent. carbon, it is made up after slow cooling of (1) some excess cementite (C), and (2) some pearlite (P = F′ + C′), and we have

$$(1)\quad C + P = 100$$

$$(2)\quad \frac{6{\cdot}67}{100}C + \frac{0{\cdot}80}{100} = R$$

If the alloy contains, for instance, 1·50 per cent. carbon, its proximate composition will be

	Per Cent.
Pearlite (P)	88·07
Excess cementite (C)	11·93
	100·00

and its ultimate composition

	Per Cent.
Eutectic ferrite (F′)	77·50
Eutectoid cementite (C′)	10·57
Excess cementite (C)	11·93
	100·00

or again

	Per Cent.
Eutectoid ferrite (F′)	77·50
Total cementite (C + C′)	22·50
	100·00

3. If the alloy contains from 2 to 4·3 per cent. carbon, it should be made up after slow cooling of (1) pearlite (P), (2) excess cementite (C), and (3) graphite from eutectic (G′), and we have

$$(1)\quad P + C + G' = 100$$

$$(2)\quad \frac{0{\cdot}80}{100}P + \frac{6{\cdot}67}{100}F + G' = R$$

The value of G′ is to be obtained from the composition of the metal after solidification.

If, for instance, the alloy contains 3·5 per cent. carbon, then $G' = 1{\cdot}53$, and the proximate composition will be

	Per Cent.
Pearlite (P)	78·35
Excess cementite (C)	20·13
Eutectic graphite (G′)	1·52
	100·00

and its ultimate structural composition

	Per Cent.
Eutectoid ferrite (F′)	68·95
Eutectoid cementite (C′)	9·40
Excess cementite (C)	20·13
Eutectic graphite (G′)	1·52
	100·00

or again

	Per Cent.
Eutectoid ferrite (F′)	68·95
Total cementite (C + C′)	29·53
Eutectic graphite (G′)	1·52
	100·00

4. If the alloy contains over 4·3 per cent. carbon, it is made up after slow cooling of (1) excess graphite (G), (2) eutectic graphite (G′), (3) pearlite (P), and (4) excess cementite (C), and we have the following relation between these constituents:

$$(1)\quad P + C + G + G' = 100$$

$$(2)\quad \frac{0{\cdot}80}{100}P + \frac{5{\cdot}67}{100}C + G + G' = R$$

the values of G and G′ being obtained from the composition of the metal after solidification as explained above. If, for instance, the alloy contains 5 per cent. carbon, then $G = 2{\cdot}33$ and $G' = 0{\cdot}73$, and the proximate composition of the alloy will be

	Per Cent.
Pearlite (P)	77·12
Excess cementite (C)	19·82
Total graphite (G + G′)	3·06
	100·00

and its ultimate composition

	Per Cent.
Eutectoid ferrite (F)	67·87
Eutectoid cementite (C′)	9·25
Excess cementite (C)	19·82
Eutectic graphite (G′)	2·33
Excess graphite (G)	0·73
	100·00

or again

	Per Cent.
Total ferrite (F + F′)	67·87
Total cementite (C + C′)	29·07
Total graphite (G + G′)	3·06
	100·00

In Fig. 3 of this paper an attempt has been made to give a graphical representation of the proximate structural composition, both after solidification and after slow cooling of iron-carbon alloys.

The proximate and the ultimate structural compositions of iron-carbon alloys, both after solidification and after slow cooling, will be found in the following table, for alloys containing between 0·10 and 5 per cent. of carbon.

I desire to record here my appreciation of the valuable assistance of Mr. L. D. Granger, Austin Teaching Fellow, in Harvard University, in conducting the experiments described in this paper.

CORRESPONDENCE.

Dr. **Carl Benedicks** (Upsala) wrote that several other distinguished writers, previous to Professor Sauveur, laid stress upon the fact that one point of Roozeboom's exposition of the system iron + carbon was contrary to experience, namely, the assumption of the transformation: mixed crystals (austenite) + graphite → cementite . . . (1), taking place by cooling at a temperature of about 1000°. To the already published experiments or known facts, which challenged that reaction, Professor Sauveur now added some new experiments, executed with the greatest care, which it seemed to him (Dr. Benedicks) were the most important part of the research, making them all much indebted to their originator. He entirely agreed with the author, that those experiments were good evidence of the fact that that point in Roozeboom's work did not correspond with facts—as Roozeboom himself was now inclined to admit.* He believed it necessary, however, as Professor Sauveur was opposing Roozeboom's argument, to point out that the line IJ, by which evidently Roozeboom's line EFH was meant, was not supposed to be any argument for the transformation (1): it was only in the diagram an *expression* of that assumption.

The reason for Roozeboom's admitting the reaction (1) was the following (and he thought it was of considerable interest to make it clear): (*a*) The slower the solidification of pig iron, the more graphite and the less cementite occurred. All authorities agreed in considering that as proving that graphite was, at high temperature, the stable form for carbon, and the cementite the unstable form. (*b*) On the other hand, experience made it clear that the cementite, at lower temperatures, had considerable stability, making it possible to treat iron and steel (repeatedly) mechanically and thermally without the cementite being decomposed. In that case graphite was but rarely formed, otherwise the use of steel in practice would be seriously affected. Now, that experience might easily lead to the assumption—if the nature of steel were superficially considered—that the cementite was, at lower temperature, the stable form for carbon. Roozeboom, in his justly celebrated work, had made that assumption. From that it followed with absolutely logical necessity, that in the diagram one horizontal line EFH (=IJ) must be drawn, indicating that the reaction (1) took place. No data being available, the line had been drawn by way of suggestion at about 1000°.

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* *Journal of the Iron and Steel Institute*, 1904, No. I. p. 257; *Zeitschrift für Electrochemie*, vol. x. (1904), p. 489.

It seemed unnecessary to point out that, starting from the assumptions made, an absolutely correct application of the phase rule was given by H. W. Bakhuis Roozeboom, "who had done far more than any one else to show the importance and signification of Gibbs' phase rule" (Bancroft, 1897). Thus when Professor Sauveur criticised that application, his arguments were made possible only by his taking the phase rule in a somewhat different sense than that given by Gibbs. Gibbs' phase rule was certainly applicable to mixtures. It had only to be observed that a mixture (even an intimate one) of two phases was not to be looked upon as a special phase. A steel constituted only of pearlite must be considered as formed of two phases, ferrite + cementite.

The phase rule of Gibbs showed that an austenite + cementite + graphite system could not form a stable equilibrium at a series of temperatures, the number of the components of the system being only two (Fe + C). Either cementite or graphite must therefore disappear; no indication was given as to which of them. In the instance adduced by Professor Sauveur, austenite + cementite + pebbles, there was, according to Gibbs' phase rule, possibly a stable equilibrium at a series of temperatures, because the number of constituents was at least three (*e.g.* $Fe + C + SiO_2$). When, for instance, in Sauveur's photomicrographs, co-existing austenite + cementite + graphite were seen, it could with certainty be inferred that equilibrium really did not exist; it was only necessary to discuss whether graphite (as Roozeboom admitted) or cementite would disappear.

The fact was, however, that a more detailed study showed that cementite was not, as Roozeboom admitted, a stable compound, but that graphite, likewise at lower temperatures, was the really stable constituent. As a consequence of Roozeboom's assumption, it was found, by application of Prof. Le Chatelier's theorem, that the cementite should be an exothermic compound; while the calorimetric work of Troost, Hautefeuille, and E. D. Campbell on the one side, and the synthesis of Moissan with other facts on the other side, proved that cementite was an endothermic compound. That being so, all reasons for admitting the reaction (1) fell to the ground, and the inevitable consequence was, in other words, that the line EFH (=IJ) must be removed from the diagram.

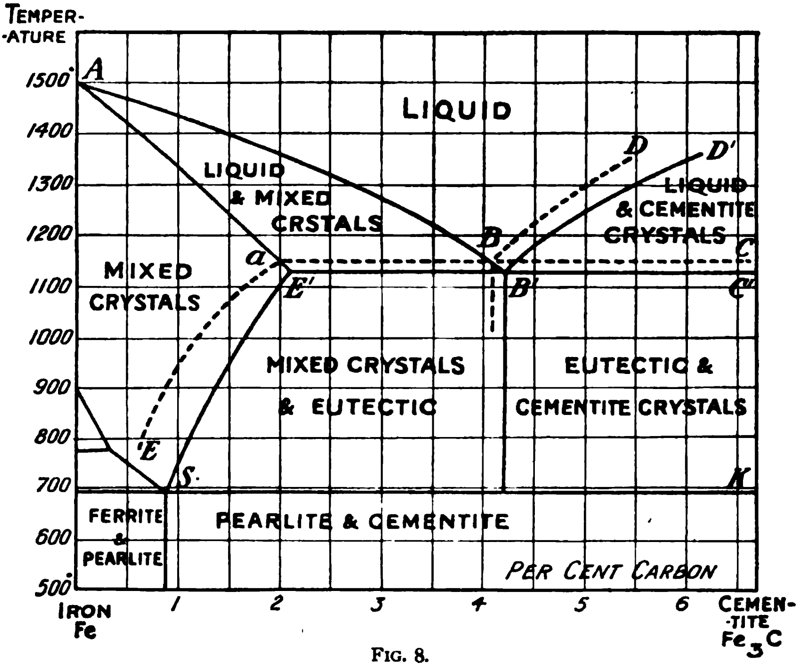

FIG. 8.

The plain lines and the designations of the constituents belong to the *metastable equilibrium* (iron + cementite); the dotted lines belong exclusively to the *stable equilibrium* (iron + graphite).

The diagram which correctly summed up the present knowledge of the system, iron + carbon, was shown in Fig. 8.

It was not possible for him to enter into a discussion of the other less significant modifications brought forth in that modification of the diagram. He referred those interested in a detailed historical *exposé* of what had been written on the subject, and in an analysis, which claimed to be logical, of the present knowledge, to his own recent work.*

In a later part of the paper, Professor Sauveur entered upon the evolution series, austenite-martensite-troostite-pearlite, and formulated in that connection a great number of questions. It would lead too far to take up all those questions. He therefore only intended to deal with one of them, namely, whether it would not be logical to infer that the troostite was a solution of carbon in α-iron? He agreed with Professor Sauveur in considering that that could scarcely be called illogical, as the experimental facts were very scanty in that respect. He wished, however, to point out that as he had shown in a short article,† it was easy, from a physico-chemical point of view, to explain the nature of that constituent satisfactorily, without creating any special hypothesis as to the allotropic state of the iron contained in it. On the other hand, he entirely agreed with Professor Sauveur in considering austenite as a carbon solution in γ-iron, and martensite as a carbon solution in β-iron: he thought there were definite facts to adduce in support of that view.

Mr. **Henry C. Boynton** (Trenton, New Jersey, U.S.A.) wrote that he fully agreed with Professor Sauveur's interpretation of the Roberts-Austen-Roozeboom diagram. He was firmly convinced that when once graphite was formed in iron and steel, it remained so under all heat treatments at temperatures not above the melting point, for graphite was one of the most stable substances known under moderate, and even at very high temperatures. In that discussion, however, temperatures above 1100° C. did not need to be considered.

He had made a number of experiments with high carbon steels and cast irons, ranging from 1·50 to 4·00 per cent. carbon, by heating them for a long time at 1000° C., followed by very slow cooling, in order to get coarse microstructures, and had always obtained small particles of graphite as a result, but he had never observed the reverse change from graphite to cementite, even with samples containing as high as 4 per cent. of carbon, nearly all in the form of graphite.

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* C. Benedicks, "*Über das Gleichgewicht und die Erstarrungsstrukturen des Systems Eisen-Kohlenstoff.*" *Metallurgie*, vol. iii. (1906).

† *Journal of the Iron and Steel Institute*, 1905, No. II. p. 352.

Professor Sauveur had considered troostite to be a solid solution of carbon in α-iron. Osmond had previously styled it a transition form between martensite and pearlite, a conclusion which did not interfere in the least with Sauveur's reasoning. An interesting comparison could be made of the conclusions reached by various recent writers and Professor Sauveur's views. Rogers [*] seemed to consider that troostite was a mixture of ferrite or cementite with a solid solution of the two in γ-iron. Kourbatoff,[†] in a very interesting paper, in which he brought forward many new etching reagents, which were of great value in determining the constituents of hardened steels, believed troostite and sorbite to be solutions of elementary carbon in α-iron. Martensite he considered a solution of cementite in iron.[‡] Benedicks,[§] in a paper entitled "The Nature of Troostite," was drawn to the conclusion that troostite was a pearlite with ultra-microscopically small particles of cementite, containing more or less hardening carbon.[||] He thought troostite presented an analogy to the "colloid solutions" of physical chemistry. Arnold [¶] considered the "dark constituent obtained by quenching a eutectoid steel during recalescence," which he did not wish to call troostite, to be an "indefinite molecular mixture of hardenite and of pearlite, in which the carbide [**] had been trapped in the emulsified or 'sorbitic' condition." The troostite of an under-saturated steel he considered an "indefinite molecular mixture of hardenite and unsegregated ferrite." He objected to classing such "indefinite and variable substances" as constituents, and proposed to call them "troostitic areas," because they liberated hardening carbon on etching. To the above opinion should be added his

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[*] *Journal of the Iron and Steel Institute*, 1905, No. I. p. 485.

[†] *Revue de Métallurgie*, 1905, vol. ii. p. 169.

[‡] *Loc. cit.*, p. 185.

[§] *Journal of the Iron and Steel Institute*, 1905, No. II. p. 352.

[||] *Loc. cit.*, p. 362.

[¶] *Journal of the Iron and Steel Institute*, 1905, No. II. p. 27.

[**] *Loc. cit.*, pp. 34, 35.

(Boynton's) former opinion,* that troostite was β-iron containing no carbon. Kourbatoff differed only from Sauveur in that he considered the carbon to be in the elementary form, while the latter said "that it never has been shown conclusively that it was carbon rather than a carbide which was dissolved by the iron." Benedicks considered that most of the carbon dissolved in the iron was cementite, but modified his conclusion by the statement that troostite contained more or less hardening carbon which he manifestly did not consider to be cementite. He did not commit himself as to the state of the iron. Arnold, since he did not accept the allotropic theory, considered that the carbon was in the form of cementite and hardening carbon; the latter condition he did not define. His (Mr. Boynton's) old view, which was the result of research work done in the academic year 1902–3, and based upon facts then at his disposal, was that troostite might be a form of carbonless iron. That conclusion he presented very tentatively, and in no sense wished to convey the impression that his conclusions formed an irrefutable hypothesis or theory. He had distinctly stated that if he had erred, he hoped that prompt criticism would bring out the mistakes. In fact, the paper was published with the deliberate intention of bringing before the scientific world the few additional facts, resulting from his observations, upon a constituent the existence of which had, up to that time, been somewhat doubted. If by definition, troostite were considered to be the component found in hardened steels which coloured very rapidly to a brown or black, far before the other constituents (and that seemed to have been the original definition proposed by Osmond, and there was no good reason why it should not be retained), then in all fairness he would claim that since his last paper he had found troostite in steel varying in composition from 0·20 per cent. to 1·78 per cent. of carbon. He had not yet found it in a eutectoid steel, and he had also heated to a white heat one end of a piece of white cast iron containing 3·50 per cent., and quenched as described in his previous paper, but did not find it. It would seem that such conditions in so highly carburised a piece of iron would distinctly favour the formation of troostite, but the presence of impurities in the cast iron treated might have been the cause of that failure. Since his paper was published, the discovery of many new etching reagents, particularly the solution of 4 per cent. picric acid in alcohol and sodium and potassium picrate in excess of alkali, which coloured only cementite, together with many other methods mentioned by Kourbatoff, had enabled him to study rather more closely the behaviour of troostite and sorbite, which, as was well known, might be partially or wholly overlooked by too rapid an attack, as when aqueous solutions of nitric acid, for example, had been the only reagents used. On repeating the etching with picric acid and examining the specimens referred to in his previous paper, however, he could alter his opinions but little. As the result of a great many more experiments made by quenching all sorts of steel heated to a white heat at one end while the other end remained cold, he had not been able to reproduce the mechanism of change of constituents which he obtained before in his hypo-eutectoid steel. The hardness of troostite, a point which he had lately investigated with some detail, seemed very closely to confirm the view of Professor Sauveur. It was softer than martensite and harder than pearlite, and its hardness remained constant in any one specimen. In his Carnegie Scholarship Report he had fully described how he had obtained those results, and it would suffice to say that, from a piece of 0·58 per cent. carbon steel, hardened only at one end, and ground and polished longitudinally, he found that while sorbite increased gradually from 2000 (the hardness of pearlite) to 25,000, the hardness of troostite in any single specimen remained quite constant at 40,000, and martensite reached the climax at 105,000. That uniformity in the hardness of troostite seemed to strengthen Professor Sauveur's views, for it could not be so if troostite were, as Arnold suggested, "indefinite molecular mixtures of hardenite and pearlite, or hardenite and unsegregated ferrite." He (Mr. Boynton) hoped that further discussion would clear up those questions absolutely. The figures mentioned above were of course relative, and could be reduced to the simpler form. If the hardness of pearlite (now 2000) were considered as unity, the ratios would stand as below:—

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* "Troostite," *Journal of the Iron and Steel Institute*, 1904, No. I. p. 262.

Constituent.	Hardness Number.	Ratio.
Pearlite	2,000	1
Sorbite	2,000–25,000	1–12·5
Troostite	40,000	20
Martensite	105,000	52·5

The above figures were in round numbers, but showed in the sample referred to that troostite was about twenty times as hard as pearlite, and not quite half as hard as martensite, sorbite occupying an intermediate position between pearlite and troostite. In the same specimen (0·58 per cent. carbon), beginning at the hardened end, the following microstructures were obtained by etching with 4 per cent. picric acid in ordinary alcohol.

	Hardness of Dark Constituent.
(1) Ferrite + well laminated pearlite, whose hardness is	2,000
(2) Ferrite + pearlite less laminated, ,, ,, ...	2,400
(3) Very little ferrite + sorbite, ,, ,, ...	4,500
(4) 100 per cent. of sorbite, ,, ,, ...	12,000
(5) Same continuously increasing in hardness . . .	15,000–25,000
(6) Sorbite + little troostite, the hardness of which is . . .	40,000
(7) Martensite (105,000) + network of troostite	40,000
(8) 100 per cent. of martensite with a hardness of	105,000

That series of structures, with their accompanying hardness numbers, entirely contradicted his previous results, and while the first observations and conclusions were honestly made, he deemed it only the duty of any conscientious scientific worker to revise his opinions as soon as possible when he found them faulty, rather than keep up a useless discussion for the sake of argument alone. He certainly felt much pleased to find that Professor Sauveur's paper had, to his mind, cleared up, in a very logical way, several hitherto unsatisfactory points of the Roberts-Austen-Roozeboom diagram.

Professor H. Le Chatelier (Paris) considered that the conclusions at which Professor Sauveur had arrived did not present any difficulties, and were fully in accordance with the views usually held. Nevertheless, their author presented them as though they were in contradiction to the ideas of his predecessors A certain degree of confusion might therefore result which he thought it was necessary to clear away. Before dealing with those conclusions themselves, it might be useful to make certain reservations on the subject of the general considerations formulated in the body of the paper. Professor Sauveur endeavoured to establish a line of demarcation between the solid state and the liquid state; he assented to the application of the phase rule to partially liquid systems, but, on the other hand, contested its application to systems which were entirely solid. Now the phase rule ignored the so-called solid, liquid and gaseous states, the distinctions between which possessed no scientific basis. Those distinctions depended indeed on the greater or smaller values of the coefficients of viscosity. It was only a question of degree, the continuity between the hardest solid and the most rarefied gas being complete. Molten iron was liquid in comparison with the same metal taken at the ordinary temperature, but it might almost be taken for a solid when compared with highly mobile liquids, such as ether, while solid iron itself might be considered to resemble a liquid when its properties were contrasted with those of the diamond. There were, as a matter of fact, only two distinct states of matter, the amorphous state and the crystalline state, yet the phase rule did not recognise even that difference. It concerned itself solely with the non-miscibility of phases, and no one could be justified in endeavouring to limit the range of its application. The only reservation that should be made—one which, however, was essential—was that the phase rule applied only to systems in equilibrium. Now in nature a perfect equilibrium existed nowhere; it was a finite condition which could only be approached more or less closely according to circumstances, and the phase rule defined the conditions of those finite states which matter constantly tended to approach. In the phenomena of chemical equilibrium, the difficulty of reaching a condition of equilibrium depended in great measure on the viscosity of the bodies concerned; in liquid or gaseous systems the disparity was often so low, that it escaped the means of observation at our disposal, and the consequences of the phase rule were therefore variable in their most rigid interpretation. In the case of wholly solid systems, the arrestation of the transformations and the phenomena of superheating and superfusion frequently rendered the state of equilibrium exceedingly difficult to attain, sometimes even enormous periods of time were required to reach it. The proofs of the results of the phase rule became scantier and scantier; iron, however, allowed the diffusion of carbon practically as rapidly as that of salt in water, and was of all solid bodies that in which the phenomena of equilibrium most closely approximated to their perfect realisation. Thus the application of the phase rule made in this case by Roozeboom was a perfectly legitimate one. Professor Sauveur discussed the question of what state the carbon was in in its solid austenitic solution. That was another question which phase rule ignored. Chemists were divided into two camps—those who interested themselves specially with theoretical speculations on the internal constitution of matter, and those who interested themselves solely with the mathematical laws of chemical phenomena. It was to the latter category that those observers belonged who had applied the phase rule to chemistry; for them a solid solution was neither more nor less than a homogeneous mixture of variable proportions of two bodies, just the same as a definite combination was a homogeneous mixture of definite proportions of two bodies. They did not ask themselves whether, in cementite, the carbon was in the condition of diamond, of graphite, or of amorphous carbon; neither did they in the case of solid solutions; those considerations had no bearing on the mathematical laws governing chemical phenomena. Professor Sauveur joined issue with Roozeboom, whom he reproached with having said that during cooling, free graphite combined with iron to yield cementite: that view was a misconception. Roozeboom had simply stated that the separation of graphite and that of cementite from the austenitic solution corresponded to two distinct curves of solubility. The truth of that statement was beyond discussion. The question could not be reopened without jeopardising the truth of the best established chemical laws. He had added, although only as a hypothesis, that according to the results of experiments which had come to his knowledge those two curves intersected, in which case there was a tendency on either side of the point of intersection to a transmutation between the graphite and the cementite in one direction or the other, according to the relative position of the two curves. Directly that diagram was published, he took occasion to point out that a number of experiments unknown to Roozeboom, among others those of Mannessman, seemed to show that the two curves in question did not intersect, the curve of solubility of the graphite being above that of the cementite: consequently the more stable condition corresponded at all temperatures to the separation of carbon in the form of graphite. Those conclusions had been fully confirmed by the earlier experiments of Charpy and Grenet, and were entirely in accord with the conclusions of Sauveur. They in no way proved the general conclusions put forward by Roozeboom, but were only particular applications of them. Sauveur's experiments showed that the occurrence of graphite and cementite in the same sample should be explained in the following manner. With extremely slow cooling, and in the absence of all passive resistances to the re-establishment of equilibrium, the cooled metal would consist of graphite and ferrite alone, that was, of two phases only, as was required by phase rule. With sufficiently rapid cooling no graphite was obtained, but only cementite and ferrite, that was to say, still two phases, but corresponding to a labile equilibrium, *i.e.* not presenting complete stability. That was the condition most frequently observed in practice; it corresponded to the production of white pig iron. The phenomenon was analogous to that of alcoholic solutions of iodide of mercury or of aqueous solutions of nitrate of potassium. Slow cooling caused the red iodide of mercury to crystallise, or, in the other instance, prismatic nitrate of potassium, and the system reached a state of equilibrium the stability of which was absolute. With rapid cooling, yellow iodide of mercury was obtained, or, in the second instance, rhomboid crystals of nitrate of potassium, corresponding to a labile state of equilibrium. Each of those varieties tended, under different circumstances, to disappear and to revert to the most stable variety obtained during slow cooling. In the same way, the cementite tended to disappear in favour of graphite, and the formation corresponded to the maximum stability; prolonged annealing also induced that transformation. With intermediate speeds of cooling it was possible simultaneously to obtain unequally stable varieties of the crystallised bodies; that was particularly easy with solutions of iodide of mercury where yellow and red crystals were seen. That was precisely what had occurred in Sauveur's experiments, where he had obtained both graphite and cementite at the same time. With the rate of cooling employed in his experiments, the more stable condition of equilibrium could be produced at the higher temperatures, starting from the liquid state. That condition corresponded to the minima of the passive resistances. At still lower temperatures, once the whole of the mass had solidified, it had been impossible to attain complete equilibrium, and cementite had separated. Each successive reheating had subsequently caused a portion of the cementite to disappear. All those results were clearly such as would have been anticipated from the phase rule. Roozeboom's diagram, as produced in Sauveur's paper, was not quite accurate. He only showed

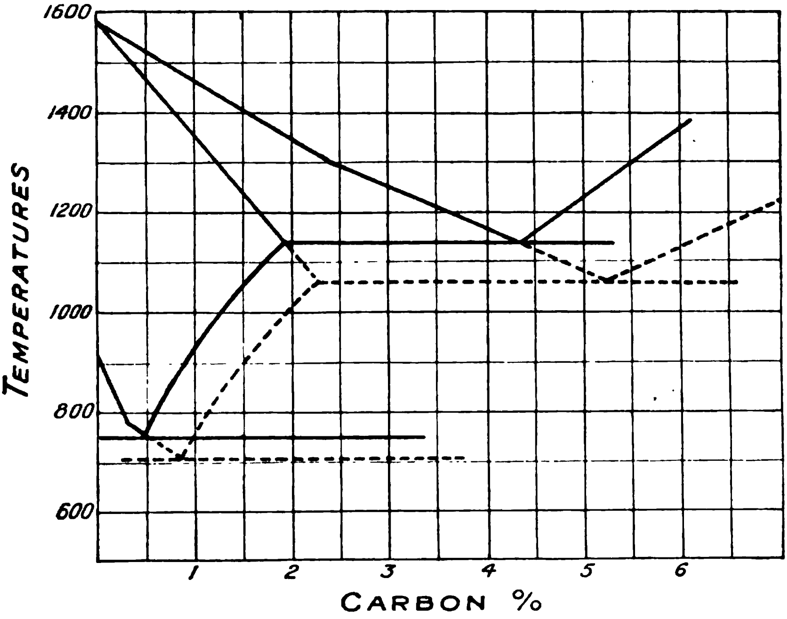

FIG. 9.

one eutectic point for the solidification of the molten metal, whereas there were really two. The late Sir W. Roberts-Austen had on his (Professor Le Chatelier's) advice pointed out the theoretical existence of those two eutectics, although he himself had only observed one, that of graphite and austenite, in the course of his experiments. The second, that of cementite and austenite, had been recently determined by Charpy. The existence of that second eutectic, cementite-austenite, furnished an immediate explanation of the line IJ in the diagram reproduced by Sauveur. That line passed through the eutectic point relating to cementite. The existence of the horizontal branch, corresponding with the commencement of the decomposition of the austenite, arose from the fact that the composition of that austenite, and consequently the temperature of its decomposition, remained constant as soon as the eutectic commenced to form. In conclusion, the complete Roozeboom diagram should be depicted as shown in Fig. 9. The straight lines correspond with states of equilibrium representing the stability maximum: the dotted lines correspond to the labile equilibrium. In practice one or other of these curves was closely approached, according to the conditions of the experiment, the height of the temperature and the duration of cooling. The presence of certain foreign elements, such as silicon, would facilitate the separation of graphite, and the reverse conditions would tend to favour that of cementite.

Professor **Henry M. Howe**, Bessemer Medallist (New York), wrote as follows: We are under obligation to Professor Sauveur for this new addition to his always interesting experiments, lucid exposition, and admirable graphical illustrations. His main contentions, I take it, are three: (1) that graphite does not normally change into cementite on cooling past the 1000° line, IJ in his Fig. 2; (2) that martensite (A) is a solid solution of carbon in β-iron, and (B) is stable between Ar3 and Ar2; and (3) that troostite is not a mere mechanical mixture of two or more normal constituents in a special state of aggregation, but is a solution of carbon in α-iron. Passing by the second of these contentions, let us consider the first and third separately. Is IJ (1050°) a graphite-cementite transformation line? According to Roozeboom's original interpretation of the diagram, in cooling past IJ, which Carpenter and Keeling show lies at about 1050° instead of 1000° as at first supposed,* graphite unites with part of the iron of the accompanying austenite to form cementite—

$$(1)\ Gr+3Fe=Fe_3C;$$

and by inference this reaction should be reversed on rising past this temperature. The author's reasoning consists of three steps:—

I. That this interpretation is unreasonable, because there is nothing to suggest even faintly that IJ differs from HI, which represents the formation of cementite, not by means of the carbon of graphite, but by means of that of austenite—

$$(2)\ \text{Austenite}=\text{austenite}+\text{cementite};$$

II. That the phase rule does not require that graphite should here change into cementite, because graphite is here inert, and hence not a phase; and

III. That his experiments show that not this supposed reaction (1), but its very opposite, here takes place on cooling.

I propose to show that the graphite-cementite change, reaction (1), was reasonably to be expected; that the persistence of graphite does offend the phase rule; and that the author's experiments are inconclusive.

The Author's Step II.—This has to be considered before his Step I. His own interpretation of his own experiments is that graphite is not inert but active, and hence a phase, for he says of his Experiment II., "a large amount of that constituent (cementite) was decomposed, and 1·038 per cent. of temper carbon formed by keeping the metal at the critical temperature of 1000° . . . and cooling slowly therefrom." Now this very separation of temper carbon, which is nothing but finely divided graphite, in and by itself constitutes activity. Under conditions which thus permit the formation of graphite, that graphite can no more be called inert than the living child in the mother's womb can be said to bear no relation to that mother. Indeed the readiness with which graphite, diamond, lampblack, and every form of carbon combine with iron at these temperatures is so notorious, that we cannot admit that graphite is here inert, except on the most conclusive and abundant evidence.

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* *Journal of the Iron and Steel Institute*, 1904, No. I., Plate XVIII. p. 227. *Cf.* Roozeboom, *id.* p. 258.

And here I should like to enter a mild protest against invoking inertness to explain infractions of the phase rule. Where a substance is truly inert (as this graphite here most certainly is not), to call it a new and additional component, and a new phase, is indeed permissible; but this seems to be juggling with words with nothing to gain. It seems, to me at least, far better to regard systems which thus contain an inert member as simply and frankly out of equilibrium, and then to face the question, "What is the change which would work toward equilibrium?" than thus to play equilibrium. This will not help us, because as soon as we reach a temperature at which this inertness ceases, the system will plainly be out of equilibrium.

The Author's Step I.—Recognising graphite as clearly active and therefore a phase, it was most natural to imagine the line IJ, to hold that it was horizontal, and that it represented reaction (1), for reasons the force of which I am sure that the author will recognise. The line HI represents the transformation—

(2) Austenite = austenite + cementite,

a two-phase system and hence monovariant, because there are two components, iron and carbon, and hence represented by an inclined line. What will become of the austenite in the region above this line when it reaches so far to the right that there is more carbon present in the mass, as a whole, than the austenite can dissolve? The excess of carbon must, if equilibrium is reached, separate out as graphite. Next, what will happen when this mixture of austenite + graphite cools to the line HI, at which we assume that the birth of cementite out of the austenite begins? What is the effect of this birth of a third phase, cementite, into the system austenite + graphite? It turns it into a three-phase system, which (if we admit only two components, iron and carbon, as to which I have something to say towards the end of these remarks) is monovariant, and therefore can be in equilibrium only at a single temperature, which we call IJ! Hence the horizontality of IJ. Therefore, on cooling from above to below IJ—or, in other words, on the birth into the system of the third phase cementite—one of the former phases should vanish, so as to bring the system back to monovariance again, so that it may persist as the temperature sinks below IJ.

This, then, is the reason for imagining the line IJ, that when the carbon-content rises so high that graphite forms, the birth of cementite here leads to nonvariance, and hence calls for the annihilation of some one phase, which can only be graphite. This is the reason why the prolongation of the line HI beyond and to the right of the carbon-content which saturates the austenite should have a new and different meaning from that of this same line where it lies at the left of this saturation carbon-content.

The Author's Experiments.—As evidence that reaction (1) does not take place, he offers the results of his experiments in which cast iron, in one case very slowly cooled past IJ (Experiment I.), and in another case held for five hours slightly below the probable position of IJ (Experiment III.), had decidedly more graphite than it should have had immediately after solidifying, provided (1) that its total carbon-content then was the same as at the end of the experiment, *i.e.* that no carbon was removed during the prolonged exposure by oxidation; and (2) that in solidifying the carbon actually distributed itself between the graphitic and the austenite states in the ratio which equilibrium calls for. If we admit these two premises, his conclusion naturally follows, that instead of reaction (1) its very opposite must have occurred; in other words, the carbon, instead of changing from the graphitic to the combined state in passing IJ, must have passed in the opposite direction, from the combined to the graphitic state.

But neither of these premises can be admitted. Much carbon may have been oxidised. His iron was indeed melted and cooled under an excess of charcoal; but for all that it may well have lost much carbon after solidifying. This is seen by comparing the carbon in his iron with that found by other observers under somewhat like conditions.

	Total Carbon. Per Cent.
In the author's cast iron (Experiment I.) slowly cooled . .	4·354
In his cast iron (Experiment III.) slowly solidified and held five hours at 1000° C.	3·630
Moissan found, in cast iron which he melted under sugar charcoal in a graphite crucible, from	7·65 to 8·17 *
Tiemann found, in cast iron which he melted under sugar charcoal in my laboratory	4·526 †

Why did the author's cast iron of his third experiment have so little total carbon, only 3·630 per cent., or much less than in any of the other cases here cited? Did it for some obscure reason simply fail to absorb more in spite of the abundant opportunity, or did it really absorb more, and was a large part of this removed by oxidation during the long heating at 1000° C.? Of the two the latter supposition seems to me on the whole the more probable, especially in view of the readiness with which carbon is removed from solid iron when thus long heated. Thus Tiemann's cast iron above referred to, in three reheatings followed by quenchings, with a total time of fifty minutes occupied by heating, lost 0·272 per cent. of carbon, in spite of being covered with a thin layer of sugar charcoal.

It is in harmony with this view that, when the cast iron made in his first experiment was held for five hours at 1000° C. in his second experiment, it lost no less than 1·484 per cent. of carbon.

It might at first be thought that the fact that the cast iron of his first experiment has so nearly the eutectic ratio, 4·354 per cent. of carbon, is an indication that this was also its carbon-content when solidifying. But on reflection this idea loses all force. His iron ought to have taken up, in melting under charcoal, more carbon than this, and though if it obeyed the laws of equilibrium (as these iron-carbon compounds so rarely do) it ought later to have expelled some of the excess graphite in solidifying, yet part of this excess ought to have remained mechanically entangled in the solidi-

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* *Comptes Rendus*, vol. cxl. p. 185.

† *The Metallographist*, vol. iv. p. 319, 1901.

fying mass. But it ought not to have expelled the whole of this excess; and by as much as was thus retained by so much ought the total carbon to have exceeded the eutectic ratio. In this case, then, we cannot admit that the iron in solidifying had the carbon-content which the author found after his long further treatment.

So much for his first premise, which I thus simply deny.

Turning now to his second premise, this, too, I deny. We cannot admit that during solidification the carbon actually distributed itself between the combined and the graphitic states in the proportions corresponding to equilibrium. I know of no evidence to support this premise, but there is much evidence that goes to show that carbon does not so distribute itself. Thus, Tiemann's cast iron, which, because it contained 4·526 per cent. of total carbon, ought, according to the author's own table, to have contained some 2·56 per cent. of graphite, yet actually had only 0·255. Three out of the five cast irons made by Carpenter and Keeling for which the graphite-content is reported, in like manner had less graphite than equilibrium would call for in view of their total carbon-content. If the evidence were all in this direction it could, of course, be disposed of by saying, with the author, that part of the graphite formed during solidification had changed to the combined state during cooling; but unfortunately for this contention two of the Carpenter and Keeling cast irons, instead of having less graphite than equilibrium would give them in solidifying actually had more (Nos. 33 and 35. See my table beyond). If this means that, in cooling from the melting point down the carbon passes sometimes from the combined to the graphitic state and sometimes in the opposite direction, this upsets his contention that graphite is inert, which is essential to his argument. If it means that, in the relatively rapid coolings of Carpenter and Keeling's large masses, enough carbon was burnt away to explain why the total graphite is above the theoretical amount which ought to be present on solidification, this upsets the first of his two premises which we are now considering. To me it seems extremely probable that the discrepancy is due partly to the burning away of carbon, but in the chief part to the failure of the carbon to distribute itself in the proportions which equilibrium would call for.

Thus his first and third experiments give no good reason to believe that reaction (1) did not take place during the long exposure to temperatures just below IJ.

Turning now to his second experiment, we find that reheating cast iron to 1000° C. for five hours, followed by slow cooling, reduced its carbon-content as follows:—

Loss of graphite	1·138
,, combined carbon	0·346
Total loss	1·484

This seems to me to mean that 1·484 per cent. of carbon was removed from the metal by oxidation during this long heating. Just how this oxidation takes place may be open to question. One way in which it is easily understood is that the exterior austenite first begins losing carbon by oxidation; that next the carbon in the underlying austenite begins diffusing or flowing outward with the effort to equalise the carbon-content of the austenite throughout the piece; and that at the same time the graphite begins passing into solution and so replacing part of the combined carbon of which the oxidation had robbed the austenite. In short, I look at this experiment as tending to show only that long heating at 1000° C. both

(1) Oxidises and removes part of the carbon, and

(2) Causes the graphite to cement the iron gradually.

In short, that what happened was a partial decarburising of the metal and a partial change of its graphite into combined carbon.

If I am right in supposing that the carbon which actually combines with the oxygen of the air and is thus removed is, at the instant of that combination, chiefly in the combined state, then the fact that the loss of graphite in this experiment is so very much greater (nearly four times as great) as that of the combined carbon seems to indicate that, in this long heating at 1000° C., a very large amount of graphite has passed into the state of combined carbon to replace a large proportion of the combined carbon which has been removed by oxidation. Whether the reason why the graphite entered into combination was that the surrounding austenite had become under-saturated, and therefore receptive of carbon by direct cementation, or that the removal of the graphite is in the direction of equilibrium, as the beginning of the vanishing of this third phase, is not clear. But in that it is a vanishing of this third and unnatural phase, it is in harmony with the belief that reaction (1) is the natural one which ought to take place at IJ.

To sum up, while his experiments seem to me very inconclusive, yet such weight as the results of the first and third experiments carry is against reaction (1), while such weight as the results of his second experiment carry is in favour of that reaction. Taking them as a whole they seem to me to make rather against than for reaction (1). Had it been possible to take dip samples in his first and third experiments, the analyses of these would have made the interpretation of his results much more valuable.

The question whether IJ represents reaction (1) is to me still an open one. I am quite aware that Professor Roozeboom has changed his mind on this point,* and I should like to call attention here to what is at least a striking coincidence in the results of Carpenter and Keeling. The following table gives the data to which I refer :—

No. of Alloy.	Total Carbon.	Graphite.			*a r m c* Present (+) or Missing (−).
		Actual.	Theoretical, on Solidifying. (Sauveur.)	Excess (+) or Deficit (−) of the Actual Graphite.	
31	3·03	...	1·05	−1·05	−
32	3·29	0·14	1·31	−1·17	−
33	3·42	1·80	1·44	+0·36	+
34	3·51	1·38	1·53	−0·15	−
35	3·87	2·14	1·91	+0·23	+

Of those of their cast irons which had enough total carbon to imply a sufficiently large separation of graphite to cause a perceptible retardation at the line IJ (their *a r m c*), the five here given are the only ones for which the actual graphite-content is given; and it is to be noted that, in all three of the cases in which the actual graphite was less than the quantity theoretically present immediately after solidification, the IJ retardation was missing; while in those two cases in which the IJ retardation was detected, the iron contained more graphite than should theoretically be present on solidification. On its face this might be taken to mean that IJ represents the change from austenite into graphite. But I for one should be very unwilling to draw this inference in the present very fragmentary state of our knowledge.

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* *Journal of the Iron and Steel Institute*, 1904, No. I. p. 258.

As the author points out, the separation of temper graphite in the annealing of the malleable cast-iron process at temperatures below 1050° C. seems to make against the idea that IJ represents reaction (1). At first it also seems to run counter to the phase rule in a surprising way; for, while it often happens that reactions which the phase rule calls for do not occur, so that we get systems out of equilibrium through lag, yet here we have a different condition of things. Here a new phase, graphite, intrudes itself apparently in the presence of austenite and cementite, and continues to intrude, not at a single temperature, but throughout a long range of temperature. The phase rule is broken not by omission, a very common thing, but through commission: not passively by lag, but actively by the persistent intrusion of a third phase into a two-component system.

But may it not be that after all the phase rule is not broken here, and that this separation of graphite takes place only when the presence of a third component, silicon, makes the presence of three phases compatible with monovariance? We should then have three components, iron, carbon, and silicon or its equivalent, and three phases, graphite, austenite, and cementite, with the silicon itself contained, probably dissolved, either in the austenite or the cementite, and therefore giving rise to no additional phase. It is in conformity with this view that in Royston's experiments, as in the common malleablising process, graphite separates freely in the presence of silicon, whereas in Tiemann's experiments with iron containing no silicon, no separation of graphite could be induced by repeated and prolonged heatings to temperatures both above and below IJ. Only when he remelted * his iron did he induce any appreciable further separation of graphite. But when he applied like treatment to iron containing 0·75 per cent. of silicon, he caused a large separation of graphite, both by heating below and by heating above IJ, followed by sudden cooling.

The belief of those who practise the malleablising process that they cannot anneal their cast iron unless it contains silicon—in other words, that they cannot induce the separation of graphite unless silicon is present—is in conformity with this view.

We need much fuller information before we can interpret the diagram with any confidence. Some things incline us to doubt whether the eutectic of the line αB is graphite-austenite, and to think it more likely to be cementite-austenite. Again, I have some reason to think that we must have two diagrams superposed, forming two eutectics, one graphite-austenite, the other cementite-austenite, of which the latter is the normal one corresponding to equilibrium; and that, except in the presence of a third component, silicon or its equivalent, graphite must at all times be an intruder, out of equilibrium.

Turning now to the second part of the author's paper, which deals so clearly with the transformations between austenite and pearlite, it seems to me underlaid by a fundamental error, that the passage from austenite into pearlite, at the right of the point G of his Fig. 2, must be through the β state instead of skipping past it. It may be true that here the β form actually is passed through, but it is still true not only that it need not be but indeed that such a passage is forbidden by the phase rule and is therefore out of equilibrium, unless we make some hardly probable assumptions.† A somewhat similar case may explain this.

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* He reports this melting as a heating; but the iron, which had some 4·50 per cent. of carbon, must have melted, because he reheated it to 1300° C.

† Because with our two-component system, iron and carbon, we cannot have more than three phases in equilibrium at once, it follows that, if austenite must pass through the phases of martensite and troostite before changing into ferrite + cementite, then the change from austenite through martensite into troostite must be complete if the phase rule is to be obeyed, before that troostite can begin to change into ferrite + cementite. This idea would give us theoretically possible systems throughout, and it does not call for more than one nonvariant system, troostite changing into ferrite + cementite. This is a wholly conceivable state of affairs, but hardly a probable one. To me, at least, it seems very much more probable that the transition is like that of evaporating ice, skipping past the stage of water instead of passing through it, at temperatures other than 0° C.

Ice evaporates at all temperatures below 0° C., so that the system, ice-steam, two phases and one component, is monovariant. Introducing here pressure as a second physical action:—

$$L=n+p-r=1+2-2=1.$$

But ice in evaporating passes through the state of water at only one temperature, 0° C., because this is a nonvariant system—

$$\text{Ice}+\text{water}+\text{steam},\ L=1+2-3=0.$$

At all other temperatures the ice evaporates directly as vapour of water, skipping by the liquid phase.

Turning back to the case of austenite changing into cementite and pearlite, and leaving pressure out of account, with our two components, iron and carbon, we can have three phases, austenite with ferrite as at the left of G (the author's Fig. 2), or austenite with ferrite as between G and H, both monovariant systems; or austenite + ferrite + cementite as at H, a nonvariant system. But we cannot in equilibrium have five phases, austenite, martensite, troostite, ferrite, and cementite simultaneously, nor can we have any four of them. The author's views would imply the simultaneous presence of four at least in the progressive change in passing GH.

Now it is quite true that troostite may conceivably be a solution of carbon in α-iron; but I see nothing in the author's argument which tends to show that it is.

Finally, if the author were wholly right, I should ask: "What is the difference between troostite and α-ferrite?" If carbon is soluble in α-ferrite, then the α-ferrite of our pearlite should be saturated with carbon; and wherein would it differ from troostite?*

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* Lest those unfamiliar with the subject be misled by a natural omission which the author, as I suppose, makes for brevity, let me point out that on p. 512, lines 10 and 11, as the alloy passes CD and begins cooling towards EF, it consists of a mechanical mixture of austenite with the constituent indigenous to his region DDDE, which is troostite according to the author, but α-ferrite according to the generally accepted theory. As the temperature progressively falls, the carbon progressively concentrates into a progressively decreasing quantity of austenite, while the quantity of α-ferrite correspondingly and progressively increases. CD, in short, represents, not an abrupt jump of the whole of the austenite into ferrite, but the beginning of a gradual change from the former state into the latter.

The two must be identical whenever any carbon is present in the mass as a whole. The fact that some cementite forms even when there is as little as 0·05 per cent. of carbon indicates that *a*-ferrite, which according to the author must be the same as troostite, cannot contain as much as 0·05 per cent. of carbon; but this is certainly not the idea which most of us have formed about troostite.*

Baron JÜPTNER VON JONSTORFF (Vienna) wrote that the ever-increasing interest which was being shown in the study of alloys in general, and in the alloys of iron in particular, caused every critical communication on the subject to be thankfully received, and that was more especially the case when it proceeded from such a well-known authority as in that instance. Owing to the enormous difficulty which experiments on the equilibrium relations of the iron alloys offered, since not only did they themselves appear to present a series of varyingly stable equilibria, but also in many cases an equilibrium which was only very slowly reached, and which was easily upset by further cooling (super-cooling), some slight differences of opinion were not undesirable, as they could assist somewhat to clear the view.

Starting with Roozeboom's diagram, Professor Sauveur divided it, for facilitating the subject, into three zones, of which the first two related to the solidification of molten iron-carbon alloys, whilst the third embraced those changes which took place in the already solidified alloys upon further cooling. Zone I. thus embraced those alloys which, immediately after solidification, consisted only of a solid iron-carbon (or iron-iron carbide) solution, whilst the solidified metal of zone II. contained graphite also, or at least might contain it. Perhaps it might also have been judicious to have divided zone III. into two parts—the one, zone III*a.*, reaching from the axis of the ordinate to the point J, and zone III*b.*, which would contain the remaining part of Sauveur's zone III.

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* The recalescence, *ar*1, has been detected repeatedly in very low carbon steel: by Osmond in steel with 0·05 carbon (*Transformations du Fer et du Carbone*, p. 56); by Arnold in steel with 0·08 carbon and 1·41 per cent. tungsten (*Journal of the Iron and Steel Institute*, 1894, No. I. pp. 107, 115, 143); and by F. C. Wallower in my laboratory in steel with 0·055 carbon. The detection of the recalescence means that the quantity of carbon which passes out of solution and into the condition of cementite is large enough to generate enough heat to cause a perceptible retardation. If the presence of 0·05 per cent. of carbon leads to the separation of enough cementite to cause a perceptible retardation, then something decidedly less than 0·05 per cent. must suffice to saturate the ferrite; for the retardation caused by an insignificant separation of cementite could not be detected.

Fig. 3 was a combination of the diagrams on the solubility equilibrium of iron and carbon (a concentration-temperature diagram) in the first and third division of the diagram, with other diagrams (divisions 2 and 4 of the figure) which indicated, in Sauveur's well-known clear way, the composition of the metal at the end of the transformations under review. That should be clearly understood, in order to avoid misunderstandings. On those grounds it would perhaps have been well to have separated those various diagrams sharply from each other, and to have put them alongside, or better, under each other.

That the curve HJ (Figs. 1 and 2), with a percentage of about 2 per cent. carbon, suddenly took the horizontal position IJ, might be readily explained by the fact that the austenite formed on solidification (the solid carbon solution) could in no case contain more than about 2 per cent. carbon. The point at which such 2 per cent. carbon solution and cementite began to separate from each other was the point I. Since every iron alloy with more than 2 per cent. carbon after solidification contained austenite, the separation of cementite would, in such alloy, also take place at the temperature corresponding to the point I. The course of the cementite-separation curve in such an alloy would have to be a horizontal one. Upon that depended the reason for the division of Sauveur's zone III., as proposed above. In any case, the point I would have to be joined through one or more lines with the point D, as was also the case in Roozeboom's diagram. Unfortunately there were no experimental data which would give safe explanations on the course of this junction. Certainly the data of Carpenter and Keeling would indicate that the line AD could undergo a prolongation in a downward direction, but it was by no means certain that it was a case of supercooling which was involved in that instance.

The experiment described by the author established the now almost universally accepted assumption that the system iron and carbon was for all temperatures under the melting point more stable than the system iron and iron carbide.

The views on the successive changes of austenite into martensite, troostite, and pearlite were ingenious hypotheses which possessed much plausibility, but which still required complete experimental proof.

That austensite at higher temperatures might be more stable than martensite, and that therefore a change of the one into the other would take place, could scarcely be doubted. To what chemical phenomenon that change corresponded was at present completely unknown. Perhaps, as Sauveur thought, in the case of austenite, a solid solution of carbon or iron carbide in γ-iron, and with martensite, on the contrary, with such a solution in β-iron had to be dealt with, but perhaps (as the writer once suggested) the first was a solution of elemental carbon and the latter of iron-carbide, both in γ-iron. In any case, however, the transformation curve between austenite and martensite was bound to be a continuous curve, which probably did not differ much from a straight line, and could in no case have a series of bends as shown in Sauveur's curve, AAAA, in Fig. 7. Moreover, assuming Sauveur's view that the transition of austenite into martensite consisted in the change from γ-iron into β-iron, that curve must pass through the critical point A_3. Otherwise that curve could take another position, and the writer had, on the ground of Carpenter and Keeling's experiments, drawn attention to the possibility that that curve might extend from the critical point of Ball (1132° C.) to a bend point in the curve HI. (The point of intersection of this curve with a horizonal observed by Carpenter and Keeling, at about 782° C.*) In any case, however, the transition point would first have to be shown experimentally.

In reference to the transition of martensite into troostite and pearlite, the writer wished to draw attention to a new work by Heyn.†

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* *Berichte der deutschen chemischen Gesellschaft*, 1906, pp. 2376–2402, and a series of articles in the *Iron and Steel Magazine*.

† *Stahl und Eisen*, 1906, p. 778.

That experimenter found that on tempering hardened steel (with 0·96 per cent. carbon) a transition product was formed, which he had called osmondite, and that that was characterised by its solubility in dilute sulphuric acid (with exclusion of air) reaching a maximum. That solubility-maximum occurred at a tempering temperature of about 400° C.

By the solution of hardened steel, which had been tempered at different temperatures, the following remarkable phenomena were observed.

On solution of untempered hardened steel practically all the carbon was evolved in the form of gaseous hydrocarbons. Such a steel contained only martensite. With increasing tempering temperature a partial transformation of martensite (into troostite, according to Heyn) took place whereby the solubility of the steel was increased, the amount of carbon escaping in the evolved gases diminished, whilst increased amounts of carbon separated in the elemental form.

When starting with a tempering temperature of somewhat over 400° C., on solution in dilute sulphuric acid, besides the foregoing, there was also a separation of iron carbide, and from that point onwards the amount of elemental carbon which separated, as well as the amount of hydrocarbons (the latter rapidly), became less.

At a tempering temperature of somewhat over 600° C. scarcely any hydrocarbons were evolved, whilst increasing quantities of iron carbide and decreasing quantities of elemental carbon separated. In that case finally pearlite was formed.

There were, therefore, in that case two series of transformations which ran concurrently—

I. Martensite → Troostite → Osmondite.
II. Osmondite → Sorbite → Pearlite.

The experimental results of Heyn which had relation to that were graphically represented in the accompanying figures, where there was also shown those relating to steel, which had been heated to 900° C. (see Figs. 10 and 11).

In that diagram the many kinks in the curve *a*, *b*, *c*, *d*, *e* had to be noted (under points *a*, *b*, and *c*). But that was only seemingly so, and was conditional upon the gradual disappearance of the hydrocarbons, caused by the appearance of iron carbide. That was evident from Fig. 1, in which the amount of separated elemental carbon had been calculated on the assumption that besides itself only hydrocarbons or only iron carbide appeared.

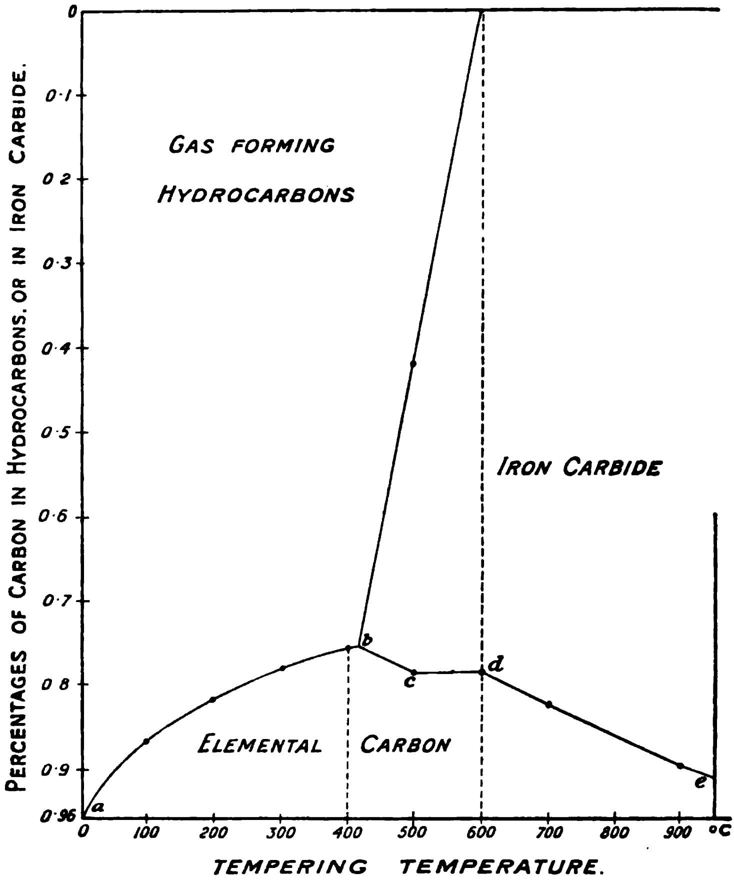

FIG. 10.

Those "rounded off" curves ran very regularly and proved the reliability of the experiments upon which they were based.

By microscopical research and the above diagrams it might be assumed that another form of the element separated out of the martensite at a lower tempering temperature, which left on solution in sulphuric acid a residue of elemental carbon. At higher temperatures cementite (iron carbide) separated itself out of the martensite, whilst the carbon con-

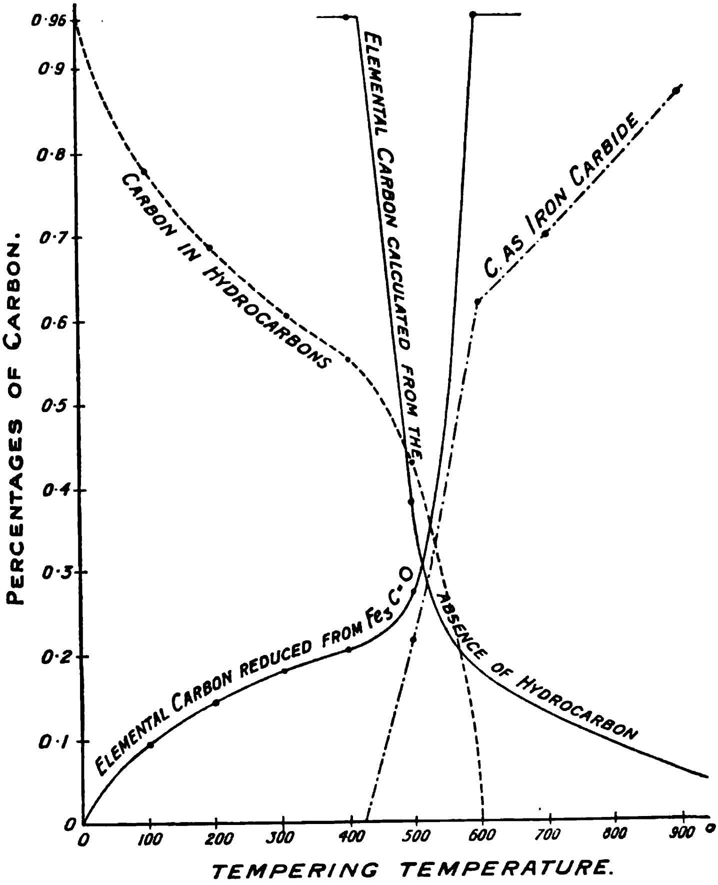

FIG. 11.

tained in the above-mentioned new form of the element gradually also was converted into carbide.

Unfortunately the experiments above-mentioned, which related to the production of a labile (over-cooled) condition, however interesting the results they gave might be, did not serve to fix the equilibrium curves for the question at issue, which could only be successfully done when the form of the element was arrived at, not by solution in a labile condition, but by the production of an equilibrium even though a metastabile one.

In conclusion he wished to mention that the phase rule held good not only for stabile but also for metastable equilibrium, and that, as Roozeboom had already rightly pointed out in his first communication on the employment of the phase-rule to iron alloys (but which was sometimes overlooked), pearlite did not present only one, but two phases (ferrite and cementite).

Mr. E. H. Saniter (Rotherham) wrote that Professor Sauveur stated that graphite which separated on solidification played no further part in the further transformations of the alloy. In his (Mr. Saniter's) opinion it did do so, but in the opposite direction to that indicated by the phase rule; that was to say, the graphite which separated on solidification encouraged a further liberation of graphite, and there would eventually be less combined carbon in the cold alloy than in one containing a lower carbon percentage cooled under similar conditions, from which no graphite had separated on solidification. That view was borne out by results given in his paper on "Carbon and Iron"* in 1897, which were as follows:—

Buttons.	No. 3.	No. 6.	No. 7.	No. 8.
Graphitic carbon .	Nil.	3·00	3·84	4·03
Combined carbon .	2·0	1·03	0·97	0·7

These buttons were all slowly cooled in the carbon-lined crucible and furnace, and the results obtained were confirmed by Professor Sauveur's experiments. It was interesting to note that No. 3 was in accord with the phase rule, the whole of the 2·0 per cent. carbon being combined, although it was slowly cooled, as above stated. It was rather remarkable that in both of Sauveur's experiments, in which he heated the alloy for a long time at 1000° C., the combined carbon was 0·94 and 0·89 per cent., which practically corresponded with 100 per cent. pearlite. On examining the photographs 5 and 6 it was evident that this was not the case, as there was either free ferrite or massive cementite present. While considering that Sauveur was probably correct in believing that graphite did not re-combine with iron to form cementite at 1000° C., it would be remembered that it was well known that cementite decomposed and liberated graphite or temper carbon at temperatures below 1000° C., when heated for a considerable time and slowly cooled. The slow cooling of his alloys from 1000° C. seemed, therefore, the weak point in his evidence, as the graphite might have combined at 1000° C., and again separated at a lower temperature. Would it not have been more conclusive to have quickly cooled or quenched one sample at 1050° C. and a second sample at 950° C. after retaining them for some time at 1000° C.? If the indications of phase rule were correct, the sample quenched at 950° C. should contain less graphite than that quenched at 1050° C.

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* *Journal of the Iron and Steel Institute*, 1897, No. II. p. 120.

Dr. A. **Stansfield** (Montreal) wrote that he quite agreed with Professor Sauveur's conclusion that cementite, in white cast iron, was unstable, and that with sufficiently prolonged annealing the greater part of the carbon would separate as graphite. He also agreed with him in thinking that Roozeboom was in error in saying that, during the cooling of cast iron, graphite and martensite combined at about 1000° C. to form cementite. Professor Roozeboom's conclusion was drawn, no doubt, from the fact that cementite formed at about that temperature, and that the phase rule did not admit the simultaneous presence of graphite, cementite, and iron in equilibrium with one another. If, however, graphite was the stable form, and cementite was unstable, and would turn into graphite and iron, if it were not for the rigidity of the mass with which it was surrounded, so that the system normally contained graphite and iron instead of cementite and iron, the phase rule would still be satisfied.

He believed the change from cementite to graphite, during annealing, would be made clearer if it were remembered that graphite as well as cementite would have a definite curve of solubility in γ-iron, and that the change from cementite to graphite was probably made indirectly through the medium of the γ-iron solution of carbon. If, at any temperature, a solution of γ-iron were in contact with graphite and cementite, and were exactly saturated with regard to the cementite, it might be supersaturated with regard to the graphite. Under those conditions, more graphite would separate from the solution, which being impoverished in that manner, would feed upon the cementite until all had been dissolved. The solution would then continue to deposit graphite until the composition corresponded to the solubility of graphite in iron at that temperature. That change, which took place slowly, was what Professor Sauveur had effected in his prolonged annealing, and the amount of combined carbon that remained might correspond to the solubility of graphite in iron at the temperature of his experiment, the carbon being then all dissolved, but separating as cementite during the subsequent cooling, or the annealing might not have been long enough to enable the complete change to take place. The conversion of cementite into graphite and iron would probably proceed more rapidly at higher temperatures, but it could not proceed so far, on account of the greater solubility of graphite in iron at high temperatures. The greatest amount of change would no doubt be obtained by prolonged annealing at a high temperature, followed by very slow cooling. In his own experiments in that direction,* and in one of the late Dr. Percy's, which he quoted in the same paper, the annealing was more prolonged, being two days in one of his (Dr. Stansfield's) experiments, and the amount of combined carbon in the resulting material was decidedly less than that obtained by Professor Sauveur. Professor Sauveur stated that the graphite formed during the solidification of an iron-carbon alloy was entirely unchanged and inert during the subsequent cooling, and that was no doubt correct, because, as the temperature fell, there was no tendency for the graphite to redissolve; but it might be supposed that the γ-iron solution tended to maintain a correct relationship with the flakes of graphite by depositing its excess of carbon on them as it cooled, and was only prevented from doing that perfectly by the mechanical difficulties attending the formation of graphite in a mass of solid iron, and by the time taken by the carbon to diffuse through the surrounding austenite to the nearest flake of graphite. In the paper already referred to he had endeavoured to make that clear, and had shown by means of photomicrographs that the change from cementite to graphite and ferrite took place more rapidly near the surface of the metal, where there would be less mechanical resistance to the formation of graphite than there would be in the interior. He also gave, tentatively, a curve of the solubility of graphite in γ-iron, and had intended to determine the latter by direct experiment. No doubt, as the temperature became lower, the formation of graphite would be attended with constantly increasing difficulty, and after the change of γ-iron to β- or α-iron was complete, it would hardly be expected that the deposited graphite would have any further relation with the iron or the cementite. He thought that Fig. 3 in the paper would be useful in conveying clearly to the mind the changes which occurred during the cooling of iron-carbon alloys, but he had extended to the left hand of the diagram the line at 1000° C., and the graphite eutectic line, and had omitted the line AD of Fig. 1. The line AD represented the conclusion of solidification of steel when the cooling was very slow, and under those circumstances there would be no eutectic in alloys of less than about 2 per cent. carbon, and the region marked "solid solution : austenite" should include the triangle to the left of the line AD as well as the space which had apparently been cut off by the dotted line through 1000°. If, however, the solidification had been very rapid, it would not be completed at the line AD, and some eutectic alloy would be found in steels having less than about 2 per cent. of carbon. For explaining the solidification of steel the line AD was essential, as it showed the composition of the crystals of steel which formed at any particular temperature, and divided off the region ADB (Fig. 1) in any part of which there existed a mechanical mixture of solid steel and liquid carburised iron, often of widely different compositions. In tracing the solidification of the iron-carbon alloys, it was well to do so in detail, and to note the composition of the crystals that first formed, and how those were surrounded by deposits of constantly increasing carbon percentage, until solidification was complete. If the cooling were slow, those crystals became uniform as the result of diffusion, and the whole mass solidified by the time the line AD was reached; but if the cooling were rapid, diffusion would be incomplete, and some eutectic would be left in alloys of less than 2 per cent. carbon. With regard to Fig. 7, he would prefer to state somewhat differently the meaning of the allotropic change points; using Sauveur's numbering:—(1) The point Ar3 in low carbon alloys corresponded to the beginning of the separation of excess ferrite as β-ferrite. That separation continued, but at a constantly diminishing rate, down to the point Ar1, only between Ar2 and Ar1 the excess ferrite which separated would be α-ferrite. (2) The point Ar2 in low carbon alloys corresponded to the passage to the α condition of all the β-ferrite which separated above that point. (3) The point Ar1 in low, medium, and high carbon alloys was due to the formation of pearlite, a mixture of cementite and α-ferrite, from the saturated residue of γ-iron carbon solution. (4) The point Ar3,2 of medium high carbon alloys corresponded to the beginning of the separation of excess ferrite as α ferrite. That separation continues, but at a constantly diminishing rate, down to the point Ar1. (5) The point Ar1 of high carbon steel had the same meaning as the point Ar1 in low carbon alloys (see 3). (6) The point Ar2 of high carbon steel, not shown in Fig. 7, was due to the separation of excess cementite. With regard to the formation of α-ferrite directly from γ-iron solution, he would not consider that it would be necessary for the iron always to pass through the intermediate β form any more than it was always necessary for water vapour to liquefy before it solidified. Professor Sauveur's paper was so wide in its scope that he had not been able to do more than touch on the more important issues that he raised, and would have to leave the remaining questions for discussion at some future time.

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* *Journal of the Iron and Steel Institute*, 1900, No. II. p. 327.

Mr. J. E. STEAD, F.R.S., Member of Council, considered that the author had made a careful effort to explain the significance of the equilibrium and cooling curves. It would appear that he was not quite certain whether the liquid alloys of carbon and iron consisted of solutions of carbon, or carbide of iron, in mutual solution with iron. When liquid iron containing carbon maximum was rapidly chilled, it was carbide, and not graphite which was found in the cold iron. That well-known fact had been widely accepted as evidence that the carbon existed as carbide in liquid iron. In liquid steel containing sulphur and manganese, it had equally been assumed that those two elements were in combination and in solution. They were found in that condition in the steel when solid, but the segregates in steel showed that sulphur segregates independently of the manganese, and that fact would lead to the conclusion that they were not in combination in the liquid metal, but united just before or at the point at which the steel solidified. Sulphur, however, could scarcely be compared with carbon, and reference to it was only made to show that what was found in the solid, was not evidence of the relation of the elements when they were together in liquid solution. He thought the author was correct in concluding that graphite which separated at the point of solidification did not re-combine with iron at a lower temperature; there was no existing proof that such combination took place: what evidence there was (including that advanced by the author) pointed in the reverse direction. It appeared to him that the region lying between the lines DE and IJ corresponding to temperatures 1130° and 1000° C. required much more investigation. He was not sure that there was sufficient evidence to show that free cementite did not begin to fall out of solution from 2 per cent., austenite as soon as the temperature fell below 1130° C., and that the curve HI should not be continued up to D. The author, in a previous research on steels with about 0·2 per cent. carbon, had shown that by quenching samples at gradually lowering temperatures, the ferrite and martensite progressively segregated with the temperature of quenching. A research on steel with 2 per cent. carbon, conducted in the same manner, would probably give equally conclusive results. As to whether the author was correct in concluding that troostite was a solid solution of carbon in α-iron, only most careful research on troostite itself would prove. It was probable that it was so. The suggestion from so high an authority would undoubtedly stimulate research, and it might be regarded as certain that, in time, the undisputed truth would be arrived at. Professor Sauveur's ingenious conclusions appeared to be fairly justifiable, if the initial interpretation of the cooling curves, &c. were correct. It was evident that the author had devoted an enormous amount of labour in elaborating his complete generalisations, and his work would naturally command the most careful consideration of all who were interested in such an exceedingly complex subject.

Professor **Bradley Stoughton** (Columbia University, New York) wrote that Professor Sauveur's interpretation of the Roberts-Austen-Roozeboom diagram curves unquestionably advanced the information available on that important subject, and the graphical representation of his ideas in Fig. 3, according to the scheme used by him in previous papers, would be found most useful. He suggested the addition of two lines which in fact appeared in the original,[*] and would transform Fig. 3 into Fig. 12. Those lines were theoretically essential, and the actual existence of at least one of them was proved by the researches of Carpenter and Keeling.[†]

A very interesting point was brought out by Professor Sauveur's experimental evidence that the eutectic of the iron-carbon alloys consisted of saturated austenite and graphite, and that went to show the danger of drawing deductions as to the behaviour of iron and carbon in the presence of even the minutest trace of impurities. Mr. H. P. Tiemann[‡] five years previously made an experiment similar to that of Professor

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[*] H. M. Bakhuis Roozeboom, "Le Fer et L'Acier au Point de Vue de la Doctrine des Phases." *Contribution à l'Etude des Alliages*, p. 331. Paris, 1901.

[†] *Journal of the Iron and Steel Institute*, 1904, No. I., Plate XVIII., opposite p. 242.

[‡] "The Temperature Limits for the Separation of Graphite from Martensite in Pure Cast Iron." *The Metallographist*, vol. iv., 1901, pp. 313–332.

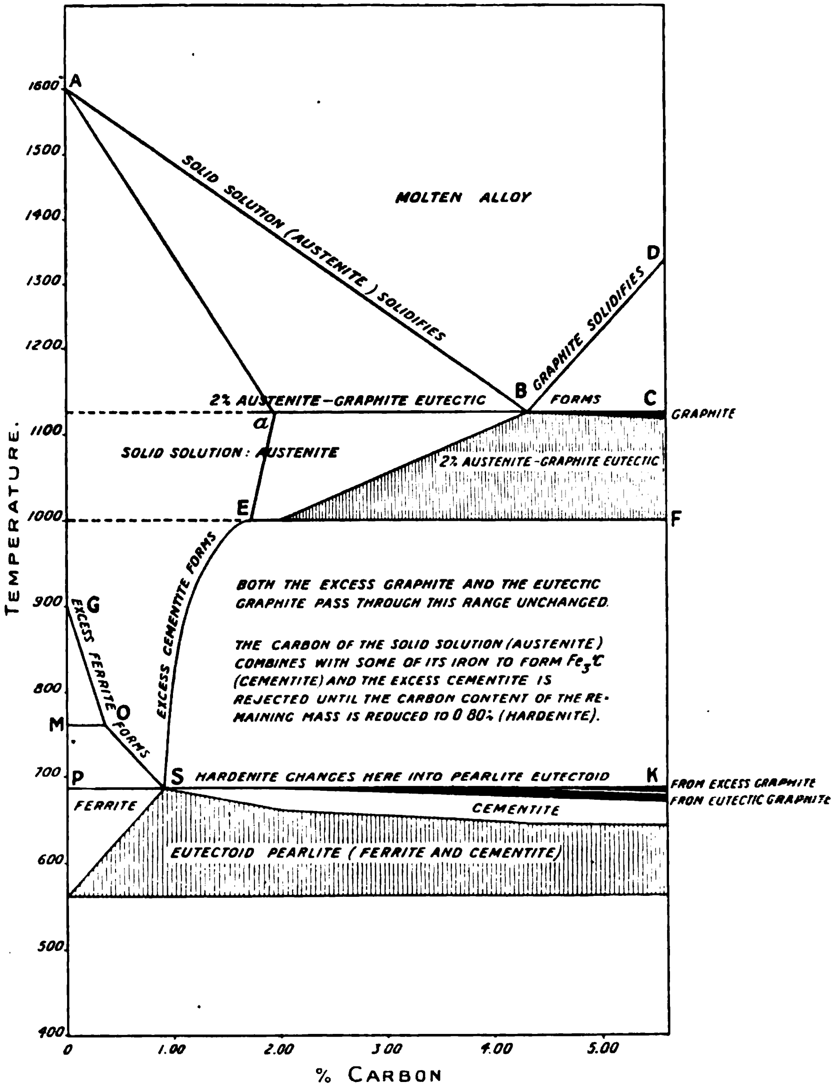
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
TEMPERATURE.
0
1.00
2.00
3.00
4.00
5.00
% CARBON
A
MOLTEN ALLOY
SOLID SOLUTION (AUSTENITE) SOLIDIFIES
D
GRAPHITE SOLIDIFIES
B
FORMS
C
GRAPHITE
2% AUSTENITE–GRAPHITE EUTECTIC
a
SOLID SOLUTION: AUSTENITE
2% AUSTENITE-GRAPHITE EUTECTIC
E
F
EXCESS CEMENTITE FORMS
BOTH THE EXCESS GRAPHITE AND THE EUTECTIC GRAPHITE PASS THROUGH THIS RANGE UNCHANGED.
THE CARBON OF THE SOLID SOLUTION (AUSTENITE) COMBINES WITH SOME OF ITS IRON TO FORM Fe3C (CEMENTITE) AND THE EXCESS CEMENTITE IS REJECTED UNTIL THE CARBON CONTENT OF THE REMAINING MASS IS REDUCED TO 0.80% (HARDENITE).
G
EXCESS FERRITE FORMS
O
M
P
S
HARDENITE CHANGES HERE INTO PEARLITE EUTECTOID
K
FROM EXCESS GRAPHITE
FROM EUTECTIC GRAPHITE
FERRITE
CEMENTITE
EUTECTOID PEARLITE (FERRITE AND CEMENTITE)

FIG. 12.

Sauveur, and reached an exactly opposite conclusion. The experiments of Mr. Tiemann were repeated several times, and gave strong evidence that, under the conditions in his case, the eutectic consisted of saturated austenite (as it was now called) and cementite. Thus two very careful series of experiments, under apparently similar conditions, produced different results. Both experimenters cooled their alloys slowly through the range of solidification, and it would appear that the differences were due merely to the traces of impurities present in each case. In Professor Sauveur's experiment the alloys contained about 0·03 per cent. of silicon; Professor Sauveur declared that to be a negligible quantity. It could hardly be said to be more negligible, however, than the impurities present in Mr. Tiemann's alloy, which contained no silicon, but had 0·04 per cent. of manganese. He brought that matter up merely to emphasise the fact that even now the composition of the eutectic of pure iron and carbon lacked absolute proof.

It was, however, to Professor Sauveur's theories of the nature of martensite and troostite to which he particularly wished to refer. He (Professor Sauveur) assumed martensite to be a solid solution of carbon in β-iron, and troostite a solid solution of carbon in α-iron, basing those assumptions on inductive reasoning without any direct proof either that such solutions were possible, or, if possible, that they existed. It seemed to him that the impossibility of the solution of carbon in either β- or α-iron was the fundamental cause of the changes that occurred along the line GOS (Fig. 12).

It was known that it was the impossibility of the solution of solid water in solid salt that caused the simultaneous freezing and precipitation of that constituent in aqueous solutions. It was also the impossibility of the solution of solid salt in solid water that caused the simultaneous precipitation and solidification of that constituent in aqueous solutions. Similarly, it was the insolubility of solid lead and tin in each other which caused the simultaneous precipitation and solidification of each of those metals respectively, and so on through the whole gamut of similar solutions and alloys. On the contrary, it was the mutual solubility of gold and silver in each other when frozen which permitted those metals to solidify together and form a solid solution. Similarly with the metals copper and nickel and all others which formed solid solutions. Hence the old name of isomorphous mixtures for the solid solutions. Hence, too, the belief that γ-iron and carbon were isomorphous. But if β-iron were isomorphous with carbon, why did austenite begin to deposit iron at the moment that the iron began to change from γ to β, and, if it were not the change from γ to β that was the very cause of the decomposition of the solution, what was that cause? That iron and carbon had a strong chemical affinity for each other, and that that affinity must be opposed by some powerful force causing them to separate along the line GOS, is to him the only logical explanation of the facts. The very act that caused the change was, it seemed to him, the assumption by the iron of either the β or α form. If the assumption of those forms did not break up the solution, he would ask what it was that did so? Professor Sauveur, however, carried his solid solutions across the line GOS (Fig. 12) and into the areas GOM and MOSP, in which he stated (see Fig. 7) that martensite and troostite were respectively stable. If that were so, then all the accepted theories of solution would have to be completely revised. It was generally assumed, as a necessary accessory to the decomposition of solutions, that the mother-liquor or mother-metal travelled along, but never crossed, the line corresponding to GOS, successively precipitating one constituent as the temperature fell in order to maintain itself upon that locus of equilibrium. As a second line of argument, it would be well to assume a condition of affairs in accordance with Professor Sauveur's hypothesis and see what it led to. Thus an alloy containing 0·50 per cent. carbon might be taken, and it might be assumed to have cooled to a temperature of about 720° C. It would then have precipitated a certain amount of ferrite which was of course in the α form, and the residual solid solution would be across the line OS. Martensite would therefore have ceased to exist in that alloy, supposing that it were cooled slowly enough to allow time for all the changes which Professor Sauveur depicted in Fig. 7, and the solution would be composed of troostite. But the facts contradicted that, for, if the alloy were suddenly cooled from that point, it would be found to consist very largely of martensite, while troostite could barely be discerned, if, indeed, it were ever found. Furthermore, that alloy should have recovered its magnetism, according to Professor Sauveur, by the time the temperature of 720° C. was reached, since all the iron would then be in the α form, but that again was contrary to the observed facts. Again, he would instance the case of an alloy containing 1·25 per cent. of carbon at a temperature of about 800° C. That consisted of austenite with separated cementite. If it were cooled suddenly from that temperature, it would consist almost altogether of martensite, with very little, if any, troostite. If martensite were a solution of carbon in β-iron, as per Professor Sauveur's theory, then that quenched alloy should only be very slightly magnetic, such magnetism as was present being due to the cementite and troostite (if any). As a matter of fact, that alloy was so abundantly magnetic as to prove that the constituent called martensite is partly magnetic itself, and therefore could not be an undecomposed solution of β-iron.

Finally, the possibility of there being a solution of β-iron in carbon might be considered, and the doctrine of phases applied. For simplicity, first the alloy containing 0·9 per cent. carbon would be considered. Assuming that that alloy had cooled to the temperature of the point S (Fig. 12). There would then be four phases present, namely, γ solution, β solution, ferrite, and cementite. Substituting now in the phase rule and there would be—

$$(\mathrm{L}=n-m+1) \text{ or } \mathrm{L}=-1.$$

Obviously that was an impossibility; the two components, iron and carbon, could only be present in three phases at the point S, which would give a degree of liberty to the system of $\mathrm{L}=0$. To avoid that conclusion, there was only one assumption that he (Professor Bradley Stoughton) could see, namely, that at an infinitesimal temperature above S, the γ solution changed all at once into a β solution, and that that change was completed before any ferrite and cementite were precipitated. But the position would be now no better when the phase rule was applied, for it would appear that, at a single point, and at that point only, there was a β solution. Here then were two components existing only in one stage which gives a degree of liberty of L = 2. Such a degree of liberty, however, was not confined to only one point. Such a conclusion might have been anticipated, for the hypothesis that the change from γ solution to β solution would be delayed until an infinitesimal temperature above point S had been reached was so far-fetched as to carry its own condemnation with it. If such a change were to take place, the logical temperature would be at 890° C., but no evidence had ever been found to indicate that there was such a critical point in a solid solution at that point. If they tried further to introduce an α solution into the doctrine of phases, even a worse position was reached, and if the same line of reasoning were followed for any point along the line GOSK (Fig. 12), they were confronted by the same impossibility. To sum up, it seemed to him (1) that the solubility of carbon in either β- or α-iron was very doubtful indeed; (2) that proof of such solutions was altogether circumstantial and indirect, resting on supposed reasons why they should be formed; (3) that their formation as described in the paper was opposed to the theories of solutions; and (4) that the theory of martensite which assumed it to be partially decomposed austenite, explained its magnetism and its structure in a way that was impossible if it were supposed to be an undecomposed solution of carbon in β-iron.

With reference to the line IJ in Figs. 1 and 2, it seemed to him that its existence rested upon such a very uncertain foundation that it should be accepted cautiously, if at all. If it were present, it certainly did not lie in the position shown, but would be situated nearer the line DE and rising toward the right hand. In the original diagram (1), the basis upon which the line was drawn rested solely on two points of retardation which was only a fraction of the number of alloys experimented on, and in the recent researches of Carpenter and Keeling (2), the retardation points which should mark that line were absent in the majority of the cases. Finally, in all cases where that line had been indicated, no proof had been produced to show that the retardations were due to carbon rather than to some other impurity. The existence of line IJ was of more academic interest than practical importance, and, if left out of the diagrams, it would merely indicate that the decomposition of saturated austenite began immediately after solidification, instead of 100° C. lower, which was simpler, more logical, and fitted the facts as they were known just as well, besides being in accordance with the behaviour of other alloys. As far as its removal affected the annealing of white cast iron, no difficulty was met with, since it was known that a little longer exposure to temperatures below IJ produced as good an annealing as a shorter time above the line. Finally, the belief in the non-existence of that line would rather confirm than oppose Professor Sauveur's main theory of the non-intervention of graphite in any change taking place below solidification, by removing the line at which intervention had been supposed by some to take place. In the foregoing remarks he had spoken several times of the impossibility of solutions. He used those words realising of course that in every case a very limited solubility existed, which was, however, so small in amount as not to affect the points at issue.

Professor T. Turner (Birmingham) desired to bear testimony to the value of the contribution of Professor Sauveur towards the elucidation of a difficult but important subject. The way in which the diagram of the equilibrium of the iron-carbon series had been divided into three portions tended to clearness and to focus the points under discussion. He had taken special interest in Part III. of Professor Sauveur's diagram, and felt from the first that it did not correctly or fully explain what occurred when grey cast iron solidified and afterwards cooled to the temperature of the air. Nothing he had observed either with microscopic or cooling tests had given support to the view that iron, from which graphite had already separated, was capable of redissolving that graphite at a lower temperature. He thought, therefore, that Professor Sauveur had done good service in emphasising the point, as stress had been laid upon it in some quarters.

It might, however, be pointed out that the view that cooling iron did dissolve separated graphite, though originally suggested, was at once criticised by Baron H. von Jüptner, who stated that though the assumption made by Roozeboom that a reaction takes place between the mixed crystals and the graphite might be theoretically completely justified, still no support had been found in fact, since no graphite separates when cast iron is quickly cooled, though, as is well known, considerable amounts of graphite do separate when cast iron is slowly cooled.* Jüptner also quoted experiments by Saniter to prove that at higher temperatures the carbide becomes more decomposed with the production of graphite, and that in spite of the presence of cementite the carbon is able to separate as graphite.† In replying to the discussion, at the same time, Professor Stansfield appeared to agree with Jüptner, and stated that in his opinion free carbon would be more stable than cementite.

The result of these observations, and of other evidence, was that in 1904 Professor Bakhuis Roozeboom himself stated that he had given up the idea of the transformation of martensite + graphite into cementite, and referred to "the greater stability of graphite than cementite which he has accepted now in agreement with most steel authorities."‡ On this important part of the subject there would now, therefore, appear to be a pretty general agreement.

Reference should also be made to the important contribution to the discussion of this subject which has recently been made by C. Benedicks,§ who has brought forward evidence to prove that the formation of cementite is an endothermic and not an exothermic reaction, as would be required if the original suggestion were correct. Benedicks from this and other reasons concludes that the reversible transformation mixed crystals + graphite $\leftrightarrows$ cementite does not exist.

He (Professor Turner) strongly supported the use of the term "eutectoid" as suggested by Professor Howe, and recommended by Professor Sauveur.

Professor F. Wüst (Aix-la-Chapelle) wrote that the phenomena observed by the author with regard to the behaviour of graphite were identical with his own experiences. He would, however, like to point out that he had arrived at different results with respect to the line IJ in Figs. 1 and 2 of the author. By determining a number of cooling curves of pure carbon alloys with different carbon contents, some of which were free from graphite, while others contained a considerable amount, he had come to the conclusion that the line IJ must disappear from the diagram, as with 1000° C. there was no development of heat. That was to say, if IJ were to represent the separation of cementite from the saturated solution (2 per cent. austenite), then the corresponding limit would be the more clearly marked in proportion to the quantity of saturated solution present. With 6·67 per cent. of carbon there would accordingly be no development of heat. That would, however, increase as the percentage of carbon was diminished, and would attain its maximum with 2 per cent. of carbon. As such behaviour had so far not been observed, the line IJ and all hypotheses based upon it would have to be regarded as at any rate doubtful.

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* *Journal of the Iron and Steel Institute*, 1900, No. II. p. 343.

† *Ibid.*, p. 345.

‡ *Ibid.*, 1904, No. I. p. 258.

§ "Uber das Gleichgewicht und die Erstarrungsstrukturen des Systems Eisen-Kohlenstoff." *Metallurgie*, vol. iii.

Professor ALBERT SAUVEUR, in reply, wrote as follows: I am gratified at the amount of discussion called forth by my paper. From the reading of the criticisms it is apparent that, with the exception of Professor Howe, whose opinion is evidently vascillating, all the distinguished and authoritative writers who have taken part in the discussion agree with me in believing that the graphite formed during the solidification of iron-carbon alloys does not recombine on passing through the line IJ in Figs. 1 and 2 of my paper, and that Roozeboom was in error when he stated that it did. Indeed, it would seem from these remarks, and especially from Professor Le Chatelier's statement, that that was already the opinion of most metallurgists. Although I cannot quite agree with him that this view was the one already universally held, I am well aware that other writers had called attention to the probable error in Roozeboom's diagram. I am well aware that Roozeboom's conception of the meaning of the curve IJ was challenged, notably by Stansfield, Jüptner, and Benedicks, and that it was revised by Roozeboom himself in 1904. If

I did not in my paper allude to the opinions expressed by other writers who had preceded me, it was due to my desire to present the issue in such a way that it must be judged on its own merits rather than to endeavour to strengthen my case by the somewhat conflicting views of previous writers. It was my belief that I could in this way make a clearer cut issue of it, and force recognition by those who had so far ignored the objections against the theory, and if I am not mistaken my plan has fairly well succeeded. I trust that those purposely ignored will find in this explanation a satisfactory apology.

Turning now to the discussion, and especially to the exception taken by Professor Howe to the conclusive character of my experiments and of my deductions, it will, I think, be apparent that the ingenious speculations which he finds necessary to prop up a theory which he is evidently reluctant to abandon only illustrate all the more forcibly the tottering condition of that theory. Professor Howe objects to my conclusions chiefly on two points: first, because I consider the graphite as an inert substance, taking no further part in the changes occurring below the solidification range; and, secondly, because my experiments were inconclusive. As to the inertness of graphite, it is evident that Professor Howe did not quite understand my meaning. Professor Howe argues that because graphite is formed at all it implies activity, at least at birth, and therefore that substance cannot be considered as inert. What I had, of course, in mind was that once formed the substance remained inactive, and I did not mean to imply its inertness during birth. Inertness may not be the best term to use, but in selecting it I thought that I could make my meaning clearer, and it is my belief that I have succeeded. If Professor Howe can show that a single particle of graphite once formed has ever been converted into cementite by any possible treatment I will willingly withdraw my expression. But this is precisely what has never been shown, and what justified the use of the word "inertness" for that constituent with the meaning I gave to that term. Professor Howe, then, after denying this inertness, proceeds to show that the theory is a logical one if we only base it on the ability of graphite to be converted into cementite—that is, upon the very premise which I deny. It seems hardly worth while to carry the discussion on this point further, for it is evident that if the constitution of iron-carbon alloys must conform to the phase rule, then iron and graphite are the two phases constituting equilibrium, and cementite is the phase which must disappear. That view, at least, is in closer agreement with the observed facts, for we know that every attempt to promote equilibrium leads to an increase in the amount of graphite, and never to a decrease of that constituent. Indeed, the only way to obtain the two phases, iron and cementite, which, according to the theory which Professor Howe defends, represent final equilibrium, is through an extremely quick solidification of iron-carbon alloys—in other words, by precisely denying the time for equilibrium to take place; those conditions which should oppose most effectively the formation of the two normal phases are the only ones by which they can be obtained to the exclusion of others. That consideration, and that one alone, would be sufficient to show the fallacy of the theory, but it is opposed by so many other evidences as to make its position untenable.

Professor Howe questions the conclusive character of my experiments, and would explain my results by assuming that combined carbon might have formed in passing through the curve IJ, but that it was afterwards removed by oxidation. That the amount of total carbon in my samples, and especially in those of Experiments II. and III. suggest oxidation, I readily concede, although I believe that the decarburisation of these samples was only superficial. When they were sent to the analysts, however, the latter were not instructed to remove the decarburised shell, and the results of their analysis show the average compositions of the iron buttons, after careful sampling. It has seemed to me that the best way to take up Professor Howe's objections was to make a new melt, of the same stock but much larger, *i.e.* to obtain a button of iron weighing about 10 lbs., and then to utilise only the centre of the button, thus getting away from all possible effect of decarburisation. At the moment of writing I have such an experiment under way, but a request from our secretary calling for the immediate mailing of my reply prevents me from reporting the results at this time. I shall publish them shortly.

As Dr. Benedicks rightly points out, the line IJ was introduced in the diagram by Roozeboom as an expression of his belief that at 1000° C. the graphite combined with some of the iron of the austenite to form cementite, and now that such conception has been shown to be in all probability erroneous, it follows that the line must either disappear altogether or be given another meaning, or that both its course and its meaning must be modified. It is to be gathered from this discussion that most metallurgists are inclined to erase it, ending the curve HI abruptly at the point I. By doing so we apparently imply that the falling out of solution of cementite ceases abruptly when the carbon-content of the alloy exceeds 2 per cent.

Professor Le Chatelier takes great pains (and he is joined in this by Professors Howe and Stoughton, and by Dr. Benedicks) to show that Roozeboom was justified in his interpretation of the meaning of the curve IJ, and that his conclusions were based on strictly scientific reasoning, and he seems to labour under the impression that I had somehow in my paper questioned the highly scientific character of Professor Roozeboom's brilliant work. Nothing could have been further from my thoughts; and indeed my admiration for Professor Roozeboom is so great and, to me, so much a matter of fact, that I should have considered an expression of that sentiment decidedly commonplace. Professor Roozeboom's reasoning was strictly logical and scientific, but it has nevertheless turned out that he was in error when he based it on the assumption that iron and cementite were the two final phases of stable equilibrium, an error which he himself recognised, as Professor Le Chatelier remarks, soon after the publication of his now classical paper.

Referring to Mr. Saniter's remarks, when I stated that graphite once formed did not again take part in the further transformations of the alloy, I meant to say that the graphite itself did not undergo any further transformation; I did not have in mind the effect which its presence might have upon the further transformation of austenite, and I agree with Mr. Saniter that it promotes the further transformation of the latter into iron and graphite, although it seems to me that this is more a question of total carbon than of graphitic carbon, or, in other words, that the greater the proportion of total carbon the greater the ease with which graphitic carbon forms under proper conditions.

The photomicrographs of my samples do show, as Mr. Saniter remarks, an excess of cementite; but this is not in disagreement with the proportion of combined carbon reported, namely, 0·94 and 0·89 per cent., for these proportions indicate a hypereutectoid steel matrix. Mr. Saniter's reasoning that graphite and iron might have combined in passing through IJ to form cementite, but that the resulting cementite might again have been converted into iron and temper carbon on slow cooling below IJ, seems quite logical, and still it is not clear, as Professor Howe rightly remarks, that temper carbon will form in this way in the absence of silicon. The results of the experiments of Tiemann reported by Professor Howe would seem to indicate that temper carbon cannot be formed in the complete absence of silicon. Further investigation is needed to settle this important point.

In reply to Mr. Saniter's remarks that my experiments would have been more conclusive if I had quenched a piece of the iron just before reaching the line IJ, and another sample after cooling slowly through that line, I am pleased to be able to report the results of such experiments which had been carried on, but had been left out of my paper so as not to increase its length unduly. The results were as follows:—

Treatment.	Composition. Per Cent.	Theoretical Percentage of Graphite formed during Solidification.	Excess Graphite over Theoretical Amount.
Electrolytic iron melted with excess carbon; cooled slowly to 1050° C. and quenched.	Total carbon . . . 4·27 Graphitic carbon . . 2·95 Combined carbon . 1·32	2·32	0·63
Electrolytic iron melted with excess carbon; cooled slowly to 950° C. and quenched.	Total carbon . . . 4·16 Graphitic carbon . . 3·15 Combined carbon . 1·01	2·20	0·95

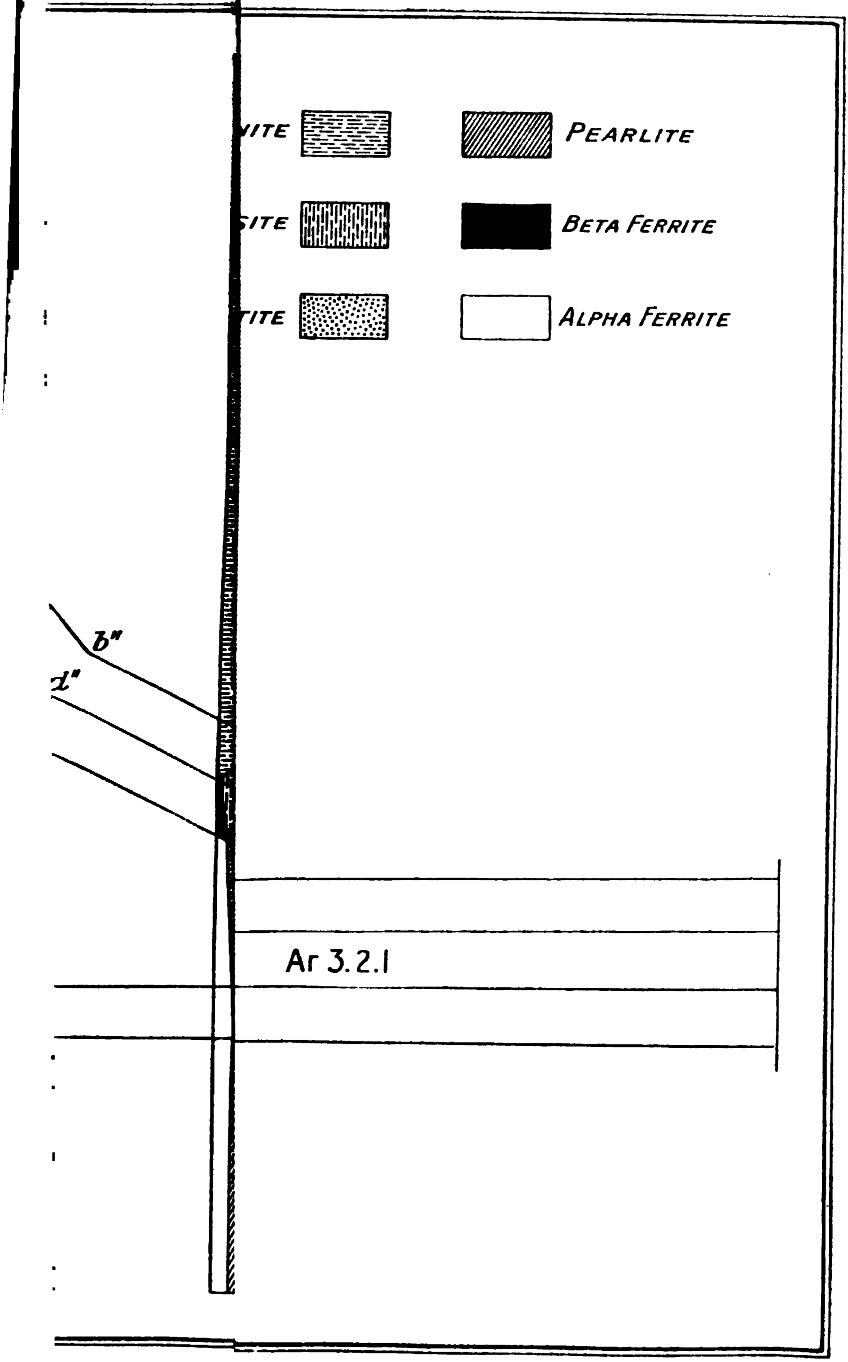
It will be noticed that in both experiments we have a excess of graphite over the theoretical amount formed durin solidification, and that in the second experiment the slo cooling through the curve IJ has increased the percentag of graphite instead of converting it into cementite.

I do not think that Professor Stansfield clearly understoo the meaning of my diagram in Fig. 3. The eutectic line an the line IJ had been extended to the left of the diagram simply to provide a space which could be used to show th composition of the alloy according to my scheme. It was not meant, of course, to indicate that alloys containing less than 2 per cent. carbon did not consist of 100 per cent. of solid solution above the eutectic line. I simply meant to indicate that after solidification those alloys consisted entirely of a solid solution, but I thought that it was clearly understood that solidification was completed along the line AD, which it would be well, as Professor Stansfield suggests, to introduce in my diagram.

Professor Stoughton considers that 0·03 per cent. of silicon is not a negligible quantity, but I am strongly of the opinion that if the alloy had been absolutely free from silicon the results would not have been materially different.

Passing now to the second part of my paper dealing with the meaning of the lower critical curves, and the nature of the constituents, austenite, martensite, and troostite, there are still evidently widely different opinions held on these questions. Some writers, and notably Professors Howe, Stoughton, and Stansfield, take exception to my way of interpreting the lower critical curves. It is clear that there is a fundamental difference between Professor Howe's conception and my own regarding the meaning of these curves, but it does not necessarily follow, as he would have it, that mine rests upon a fundamental error. I infer from these criticisms that I did not clearly explain what my conception was. In order now to do so I shall consider this subject at greater length, assisted by the diagram (Plate LII.), in which the critical points, Ar1, Ar2, and Ar3 are represented as covering certain ranges of temperature which are exaggerated for convenience of illustration. The vertical lines drawn through the diagrams

PLATE LII



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illustrate, according to a well-understood scheme, the composition of certain alloys at various temperatures.

The width of the vertical lines represent in every case the percentage of the various constituents.*

Let us first consider the point *a* in Fig. 1, and which corresponds to an alloy containing some 20 per cent. carbon. The metal here consists of a solid solution of carbon in iron, or, according to some writers, of a carbide of iron in iron. It is well to note here that Mr. Stead is inclined to think that it is a carbide and not carbon which is dissolved in the iron, and that he considers the fact that upon quick solidification the carbide Fe_3C is retained, and not graphite, as conclusive evidence that carbon is in solution in the shape of that carbide. It might be said in passing that if such be the case, then it must be logical and strictly in accordance with our knowledge of alloys to infer that the line BC of my Fig. 2 represents the formation of cementite, and not of graphite, and that the line DBE represents the formation of an austenite-cementite eutectic, and not of an austenite-graphite eutectic. I do not, however, desire at present to insist upon this point, and I will refer to the solid solution as that of carbon in iron, a solution for which the term "austenite" is, I think, at present generally accepted.

Returning to the diagram, as the alloy cools from *a* to *b* no change occurs in its constitution. When the point *b* is reached, however—that is, the critical point Ar3—a sudden and marked evolution of heat is observed. That there is here an allotropic change taking place, the iron passing from the γ to the β condition, is also generally accepted.

According to my conception of the mechanism involved, as the alloy passes through the range *bb′cc′* the totality of the iron passes from the γ to the β condition, the alloy being converted thereby from a solution of carbon in γ-iron into a solution of carbon in β-iron, *i.e.* from austenite into martensite, as clearly shown in the diagram. As soon as this allotropic change takes place, however, the iron is no longer able to be retained in solution and β-ferrite begins immediately to separate and keeps on separating through the range *cc′dd′*, as indicated in the diagram. I consider that the rejection of β-ferrite by the solution is due primarily to the allotropic change, and that the allotropic change is the primary cause of the evolution of heat taking place at Ar3.

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* I trust that this scheme will not be misunderstood by Professor Stoughton, and that he will not again accuse me of taking the solid solutions across forbidden ground, and of upsetting firmly established theories.

According to the view of some metallurgists, however, upon reaching Ar3 an excess of iron is rejected by the solid solution, and that excess only changes from the γ to the β condition, the iron in the solution remaining in the γ state, or, in other words, the solid solution being still austenite.

If I understand them rightly, the point Ar3 marks only the beginning of a change which continues all through the range *bb′cc′*. The evolution of heat at Ar3 is due to some iron beginning to separate and to pass to the β condition, and continuing to separate and to pass to the β state all through the range *cc′dd′*. If such be the case we must necessarily expect the evolution of heat also to continue all through that range, while, as a matter of fact, we have an abrupt evolution at Ar3, followed by a quick return to a normal rate of cooling, which rate remains normal all through the range *cc′dd′*. This surely suggests a marked transformation at Ar3, and not merely the beginning of a transformation extending over the range *cc′dd′*, and I take this transformation to be the abrupt conversion of the totality of the iron from the γ to the β condition, the further evolution of heat caused by the separating of β-ferrite not being apparently sufficient to cause a noticeable retardation in the cooling.

After passing the point Ar3, β-iron forms in increasing quantity, as indicated in the diagram, while the remaining solid solution, which is now a solution of carbon in β-iron and which I shall call martensite, *slides down the curve c′d″*. I put these words in italics because I have been accused of not providing for the required sliding of my solid solutions.

When martensite or the residual solution has reached the point *d″*, and all the excess β-iron has been expelled, or in other words, when the point Ar2 is reached, then a second allotropic change takes place and the iron passes from the

β to the α condition, this being true as well for the free β-ferrite as for the solution, which is thereby converted into a solution of carbon in α-iron, which I shall call troostite. As should be expected, this is accompanied by another marked and abrupt evolution of heat. This also is shown graphically in the diagram.

According to the opposite theory, it is only the excess iron which at Ar2 passes from the β to the α condition, the solution still remaining in the γ state—that is, in the condition of austenite—until the point Ar1 is reached, when austenite is changed into pearlite without passing through the β condition.

Here, again, if the opposite theory be true, the point Ar2 marks only the beginning of an evolution of heat, continuing throughout the range $ee'ff'$, and the cooling curves should show at Ar2 simply a slight change of direction, which direction should remain constant through $ee'ff'$, while, as a matter of fact, we have an abrupt evolution of heat at Ar2, followed by a quick return to a normal rate of cooling, which is strongly suggestive of a transformation occurring at Ar2 and completing itself at that point.

In cooling through the range $ee'ff'$ α-ferrite continues to form, while the decreasing troostite slides down the curve $e''e'''$, and when the point e''' is reached, the residual troostite is converted into pearlite.

The changes of constitution which I have in mind are clearly shown in Fig. 1, not only for an alloy exhibiting the three points Ar3, Ar2, and Ar1, but also for an alloy exhibiting the point Ar3,2 and Ar1, and for those having the single point Ar3,2,1, and it will not be, I think, necessary to explain at greater length the meaning implied.

I hope that I have made it clear that, contrary to the objections of Professor Stansfield and others, my conception, as well as their own, provides for the sliding of the solutions, and that, mindful of the laws of solutions, I am not taking them through forbidden ground.

To sum up, I claim greater logic for my conception: (1) because of the very appearance of the cooling curve which indicates sharp and abrupt evolutions of heat at the points

Ar3 and Ar2 followed by normal rates of cooling, and not the slight and long continued retardations called for by the opposite views; (2) because it is more readily conceived that β-iron falls out of a β-iron solution than from a γ-iron solution, and α-iron from an α-iron solution than from a β solution; (3) because it falls in line as satisfactorily as other views with the theory of alloys in general; (4) because the horizontality of the curve Ar2 supports my view, which demands that the allotropic change in the solid solution at d'' should take place at the same temperature as the similar change in the excess ferrite at d.

Professor Stoughton finds fault with my reasoning because it does not rest on any direct proof. Unfortunately this is the fate with most theories, and, if we make this a criterion of their right to exist, then most of them must disappear, and with them the allotropic theory itself. We have no direct proof of the existence of several allotropic conditions of iron, nor, indeed, have we any direct proof whatever of any of the constitutional changes which take place while the iron solidifies. We only have direct proofs of outward manifestation of those changes, such as evolution of heat, changes in magnetic properties, conductivity, &c. The moment we begin to argue as to the nature of the changes themselves we instantly step on speculative ground, and direct proofs fail us. This absence of direct proofs, however, does not affect my conception of those changes more than they affect the conception of others. We should always bear in mind that the fittest theory to-day is liable to give way to-morrow to another theory of greater vitality. The theory which must survive is the one which accounts in a most satisfactory and most logical manner for the known facts and phenomena.

Professor Stoughton claims that I am taking my solid solutions through the lines JOS of his Fig. 8 and into the area GOM and MOSP, when, as a matter of fact, I do nothing of the kind. I am simply indicating that in those areas the solid solutions martensite and troostite exist, but it will be apparent from the description I have given of my conception that I provide for the sliding of solid solutions along the proper lines, and Professor Stoughton's rather formidable statement that, if I am right, all the accepted theories of solution would have to be completely revised, falls to the ground.

I do not see that the view which Professor Stoughton develops, and which holds that β-iron, and, later, α-iron, fall out of solution because they cannot be retained in solution, is, as he considers it, fatal to my explanation of the mechanism of the changes involved. On the contrary, it appears to me that it rather supports my views, for it is precisely because the allotropic varieties α- and β-iron cannot be retained in solution that they begin to separate as soon as the allotropic changes take place within the solution; it is precisely why martensite and troostite are essentially transition constituents having but a short existence; it is why they can be retained in the cold only by denying the time needed even for an approach to a stable condition.

Professor Stoughton would deny the possibility of a solid solution rejecting one of its components, although Roozeboom himself clearly refers to this when he says: * "That a solid solution may reject one of its components as a compound just as a liquid solution does when it is cooled, was an entirely unknown phenomenon a few years ago, but it has now been demonstrated in some cases which have been the object of researches by my pupils."

The segregation of ferrite and cementite at the point Ar1 indicates that at that temperature they are no longer soluble in each other; but does it follow that they cannot dissolve each other at a higher temperature? When an alloy of copper and silver, for instance, reach the eutectic line both crystals of copper and of silver are formed, showing that the two metals are no longer soluble in each other, but they were dissolved in each other above that line. The abrupt change in their respective solubility was brought about by a change of state, the alloy passing from the liquid to the solid condition, while the sudden change in the respective solubility of iron and carbon is caused by allotropic changes, and if, with Le Chatelier, we bear in mind that the phase rule does

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* "Iron and Steel from the Point of View of the 'Phase Doctrine.'" *Journal of the Iron and Steel Institute*, 1900, No. II. p. 314.

not recognise changes of state nor allotropic changes, the two phenomena become indeed closely related.

It will not be amiss to note here that this conception of solid solutions of β- and α-irons, which Professor Stoughton seems to consider almost unthinkable, was at least considered by Roozeboom himself, who says in his original paper:* "My studies on mixed crystals led me, however, to consider also the possibility that the β- and α-iron also hold some carbon in solid solution, although less than the γ-iron."

Dr. Benedicks also believes martensite to be a solid solution of carbon in β-iron, while he considers it not illogical to suppose that troostite is a solid solution of carbon in β-iron, and Mr. Stead likewise says that such is probably the case.

I fully agree with Professor Stoughton when he says that the very act that causes β- or α-iron from separating was due to the assumption by the iron of either the β or α form, and I claim such a statement for the support of my conception. From closer examination Professor Stoughton will see, I think, that I am not constantly breaking the laws of the phase rule; that my conception of the changes do not call for a greater number of phases than permitted after equilibrium has been reached; and that, when there are more than two phases present, it is simply because equilibrium has not been reached, and that failure to reach equilibrium is generally what happens is too well known to call for further discussion.

The point of difference between the conception of Professor Stoughton and others regarding the transformation occurring at the critical points and my own is really based on the fact that they assume that when the point Ar3 is reached γ-iron falls out of solution, and is then immediately converted into β-iron; and, similarly, at the point Ar2, β-iron falls out of solution, and is immediately converted into α-iron, while I consider it more logical to conceive that the allotropic change precedes the falling out of solution of the ferrite, or, in other words, that at Ar3 the iron changes from the γ to the β state, and then begins immediately to fall out of solution; and, similarly, at Ar2, the β-iron changes to a, and immediately begins to separate.

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* "Iron and Steel from the Point of View of the 'Phase Doctrine.'" *Journal of the Iron and Steel Institute*, 1900, No. II. p. 314.

I agree with Dr. Boynton in his statement that the well-defined and constant hardness of martensite and troostite is an argument in favour of an equally well-defined and constant constitution. The varying nature of sorbite was very clearly brought out by Dr. Boynton's valuable experiments.

THE INFLUENCE OF SILICON AND GRAPHITE ON THE OPEN-HEARTH PROCESS.

By ALEX. S. THOMAS (Cardiff).

However good a furnace may be in regard to design, &c., or however excellent in the quality of the gas used, a suitable heat for the successful working of the metal cannot be obtained unless the melt be coated by a proper quantity of slag. This coating may be excessive or it may be deficient in quantity. The right degree of heat is the essential condition of successful working, for the quality of the steel made is never very good when the metal is allowed to simmer in the furnace for an excessive period, and this heat cannot be obtained if the metal is not protected by a proper covering of slag. This is not only to prevent the metal being over-oxidised and wasted, but also to prevent the metal being chilled when exposed with only a thin covering of slag.

The slag may be obtained by either of two ways: firstly, naturally, by the presence of sufficient silicon in the iron used to unite with oxide of iron to form a staple slag; or, secondly, by the addition of slag or free silica. In the first case the slag is formed naturally by the action of the oxygen in the flame—*i.e.* the oxidising atmosphere of the furnace—on the silicon in the metal when melting. The charge then melts, as it is termed, "thick," and protects the banks from being cut.

If too much silicon be present, however, and an excessive quantity of slag be formed, it will be found to be rather infusible, and unless care be taken to add the oxides quickly and follow the furnace up—thus rendering the slag more fusible by the extra oxide of iron—the furnace bottom is liable to be pulled up. In such cases the author has frequently been able to warn a furnaceman that unless he got his slag thinner and less viscous, the bottom would be "up," although no signs of such a bad bottom could be seen at the time. Another disadvantage of too high a percentage of silicon is that the metal is liable to become too hot and froths up through the slag, becoming exposed to the oxidising atmosphere of the furnace. The metal will then be burnt and carried over into the checkers as oxide (Fe_2O_3), which will be found in a fine state of division in the flues.

Provided the right percentage of silicon is secured in the iron to form a suitable slag naturally, the furnaceman can work the cast much quicker, because of the greater initial heat enabling him to add his oxides faster and so oxidise his metalloids, with an increased yield and a saving of one to two hours per charge.

Where low silicon pig is used (by low silicon pig is meant silicon under 1·25 per cent.), free silica or slag may be added to the charge to form a slag or coating to protect the metal. A certain amount of heat is taken up in melting this, and owing to the character of the iron (low silicon), oxide of iron is formed freely. However careful the operator may be, this cannot always be brought, as soon as made, into intimate contact with the free silica or slag added, so that the banks are fluxed and much damage is done to the furnace, with delay for repairs. There is also the probability of the charge breaking out. Of course, in a badly constructed furnace, or when the gas is of poor quality, causing slow melting of the charge, a greater quantity of oxide of iron is formed even with a high silicon pig, and the banks of furnaces will be fluxed, as the ferrous oxide will more readily enter into combination with the free silica from the banks of the furnace than from the silicon in the iron, owing to the low temperature of the bath.

But, given a good furnace, all the essential constituents that go towards the successful working and making of acid open-hearth steel and a low silicon iron, it will be found that the charge is often boiling before it is quite melted; for the little silicon that is present is quickly oxidised out, and the oxide of iron unites with the free silica of the banks and fluxes them badly, principally on the slag line. The damage to the banks is therefore done before the charge is in condition to receive the iron ore or other oxides to oxidise the remaining metalloids, or to receive the benefit of the silica in the ore, which might have entered into combination with the oxide of iron to form a stable slag and so have protected the banks.

The author has always found that where low silicon pig is used a great loss of iron takes place, not only by oxidation through exposure to the flame of the furnace, but also by the loss of iron in the oxides owing to the smaller quantity of oxides which are used. Again, there is never the same vigorous action in the furnace when low silicon pig is used, owing to the lower initial heat in the charge when molten. A loss of fuel is also attributable to loss of heat by the scanty slag being unable to retain the heat of the metal, as the metal readily chills when unprotected by a good siliceous slag.

The argument is put forward by some iron manufacturers that, with the smaller percentage of silicon, the steelmaker gains, in a corresponding degree, a greater percentage of iron in the pig iron. This may appear to be so on the surface, but supposing 25 tons of pig iron be charged in a 40-ton charge, a difference of even 1 per cent. of silicon means 5 cwts. of iron, and far more than this is oxidised and wasted, not to mention the extra time taken in working the cast, and the delay in repairing the furnace banks.

Again, a 40-ton furnace charging cold material will make 3½ tons of steel per hour, so that if a charge of low silicon pig takes one to two hours per charge longer, it means that 3½ to 7 tons less steel are made, with a consequent rise in the cost of fuel, labour, &c., per ton of steel actually produced.

Regarding the making of a slag artificially, the author believes this to be necessary only in the manufacture of high grade steel, where the time taken to work a cast is not of much moment and the yields are never thought of. In this case an extra quantity of slag would reduce the rapid oxidation, and aid in the production of high carbon steels. It would also eliminate any tendency of the metal to become "wild" by reducing the amount of active oxide in the slag. For the ordinary grade of steels a large output and a good yield is only obtained by having enough silicon in the iron to form a natural coating—neither scanty nor excessive—but just sufficient to allow of the rapid additions of oxides and oxidation of the metalloids.

The author's experience of high silicon and low silicon pig is that, when using pig with silicon of 2 per cent. and over, the banks are seldom, if ever, fluxed; but that bad bottoms very often occur if the furnaceman lags behind, and does not add his oxides quickly enough to keep his slag from becoming viscous. When using low silicon pig (1 per cent. and under) the banks are invariably fluxed, but the bottom of the furnace very seldom comes up. Therefore, in the acid open-hearth process, a middle course must be steered by using an iron with the silicon neither very high nor yet very low, and the author's experience is that a silicon containing from 1·25 per cent. to 2 per cent. is an ideal one for the acid open-hearth melter.

There is no doubt that the up-to-date iron manufacturer is handicapped when making high silicon iron (above 1¼ per cent.), and the acid steel maker is also handicapped when using iron under 1·25 per cent. To bring the steel maker into line with the iron maker, the author would suggest that in furnaces making acid steel with low silicon iron the acid bottoms now used should be replaced by basic bottoms, and the low silicon hæmatite iron worked on the basic bottom.

This could not be called a basic process, the essential aim and feature of the basic process (dephosphorisation) being absent, and only enough lime (3 to 5 per cent.) need be added to render the slag just sufficiently basic to prevent the banks and bottoms being fluxed. It would be an acid process on a basic bottom, and the quality of the resulting steel would be superior to the average quality made on acid bottoms. The output would also be increased 15 to 20 per cent., as so much more steel scrap could then be used in the charge.

While numerous papers have been read at various times on the effect of low and high silicon, &c., in the retarding or otherwise of the process of refining iron by the open-hearth process, a very important constituent in the iron, viz., carbon in the graphitic form, does not seem to have met with the attention which it really deserves.

Mr. Talbot has given the metallurgical world one of the most interesting processes of recent years, and one in which the various reactions can better be perceived and studied than in the ordinary process of first melting and then decarburising, &c., by slow degrees.

In a 160-ton furnace where hæmatite iron is used, silicon—contrary to one's expectation—is not a trouble to the same extent as graphite. The fluxing effect of the silicon on the banks of the furnace is easily neutralised by the addition of lime, provided the approximate percentage of silicon in the iron be known; and although no mixer be used and the iron be obtained from one blast-furnace, the silicon does not vary very much, although the graphite does, and it is this graphite which retards the process of steel-making—more so even than phosphorus or high silicon would.

Generally, however, a high percentage of silicon in the iron is accompanied by a high percentage of graphite, and therefore high silicon is a disadvantage only because it is accompanied by a separation of the carbon in the graphitic form.

When a charge of iron containing a high percentage of graphite is worked, the whole bath in the furnace is covered with a layer of "kish," and sand shovels can be put into the furnace and the carbon actually ladled off the surface of the bath. When the iron is of this nature, the whole bath lies dormant until the carbon is partly burnt off and partly converted into the combined state. As soon as this takes place the bath becomes active again. Whilst the bath is lying inactive it means so much time lost and greater consumption of fuel, &c., as the furnace charge is practically at a standstill, sometimes as long as two hours. The addition of oxides or even a vigorous mechanical agitation of the bath does not in the least affect this state of affairs, and it is necessary to wait until the graphite is partly burnt off and partly converted into the combined form. When the percentage of graphite is low none of the above disadvantages are met with, as the metalloids in the iron and the oxides in the bath gently re-act without cessation, and no delay takes place. Further—whereas the average time taken in pouring a ladle of low graphite iron into the furnace is only about thirty minutes—it takes one-and-a-half to two hours to pour in an equal quantity of high graphitic iron, owing to the very violent reactions which take place.

The operation of pouring iron into the highly oxidised bath may be steadily proceeded with in the case of iron containing carbon in the combined form and low graphitic contents, as a steady reaction between oxides and metalloids takes place throughout the whole operation and until the carbon reaches the required percentage.

When the carbon in the iron is high in graphite, no reaction takes place for some time, so that only 3 to 5 tons are poured in at a time, because when the reaction does take place, from ten to thirty minutes afterwards, it is so sudden and violent that slag, and ofttimes metal, are thrown out of the doors, and the reaction is so great that the flame sometimes reaches across the stage and up to the roof of the shop, causing great pressure in the furnace. Of course, when this happens, gas and air are shut off until the reaction subsides. A few tons more iron are then poured in, and usually another long wait ensues until the oxides and metalloids react. It is this waiting, interrupting the continuity of the process, lowering the output, and causing wear and tear of the furnace and a higher consumption of fuel, &c., which renders the presence of graphite objectionable.

Usually after emptying the ladle of high graphitic iron, the longest spell of inactivity takes place, due most likely to the lower temperature of the bath, the more feeble oxidising power of the slag, and the presence of a greater quantity of graphite, which, floating on the top of the molten iron, is unavoidably poured in with the last lot of iron in the ladle. This spell of inactivity may last as long as one to one-and-a-half hours before the bath begins to boil. All this tends to show that free carbon in iron has a very marked effect in retarding the process, although far less attention has been paid to the effects of graphite than their importance demands.

The author has found that when iron with a high percentage of combined carbon was supplied, instead of highly graphitic iron, the output was immediately increased 25 per cent., and the wear and tear on the furnace was reduced 100 per cent. These figures speak for themselves. The intermediate process between the above "all molten" and the ordinary process of charging all cold materials was used for a few years, but it has been discontinued, as the desired advantage was not obtained, because the iron had to be brought direct from the blast-furnace (there being no mixer), and it was therefore impossible to get it just at the proper time to suit the steel furnaces. At the acid open-hearth furnaces 28 tons of cold material were charged, and when this was about melted 10 to 12 tons of molten iron were added. If the percentage of silicon was not too low, and the iron not too high in graphite, there was usually an hour gained on an average per charge over the ordinary process of cold charging; but when the iron was high in graphite, time was lost in decarburising, and instead of gaining an hour, an hour would be lost over the ordinary process. The foregoing applies to the effect of graphite when using molten iron. But does not the same condition of affairs exist in the ordinary process of charging cold material? When using pig iron containing a high percentage of silicon, is not the longer time taken in working such a charge—generally attributed to the high percentage of silicon—really due to the high percentage of graphite present? Why do some charges, using equal quantities of iron, with the same percentages of silicon, and practically the same percentages of total carbon, take so much longer to decarburise than others, under similar working conditions of heat, &c.? During the period of melting the percentage of carbon when in the combined form is greatly reduced by being partly oxidised in the oxidising atmosphere in the furnace, but when carbon is present mostly in the graphitic state, this reduction does not take place, as the carbon is being converted into the combined form, so that when the charge is melted a greater percentage of carbon is present to be decarburised by the oxides added. When using high graphitic iron, the author finds that less than 10 per cent of the estimated carbon contents are eliminated during the melting period. This differs greatly from the 30 to 45 per cent. given by Harbord and Campbell in their books.

CORRESPONDENCE.

Mr. E. ADAMSON (Seaton Carew) wrote that he quite agreed with Mr. Thomas that it was not advisable to use an iron too rich in silicon in acid open-hearth practice; the best percentage in the pig depended upon the scrap. In the previous May he had shown the enormous variation in silicon contents of No. 1 hæmatite, which would indicate, particularly in using cold pig iron, the necessity for the steelmaker to know the silicon analysis of each cast, and where that was not easily obtainable it would be better to sample each truck, charging the furnace accordingly, when the risk of boiling before the bath was clear melted would be reduced to a minimum. The use of low silicon pig would not necessarily mean a greater oxidation of iron, if proper precautions were taken. Low silicon and sulphur hæmatites were not so cheaply made as those of the usual silicon contents, hence they commanded a higher price. The use of such a pig on a basic bottom also had its difficulties. The lime suggested (3 to 5 per cent.) would hardly be sufficient to prevent the fluxing of the banks—it would only give a semi-basic or "bastard" slag, which he had found cut the banks on the slag line like a knife. It would be necessary, therefore, to have a true basic slag, which would give all the disadvantages of working the basic process, using at the same time what was, as yet, a much more expensive material, and it was doubtful also if such a method would not decrease rather than increase the output by reason of slower working. It would be interesting if Mr. Thomas could say exactly under what conditions—and if there are several conditions, each condition—under which free carbon or graphite occurred in Siemens practice. He (Mr. Adamson) believed graphite played a more important part in pig iron than had so far been recognised. The higher the temperature at which pig iron was made the higher the possible total carbon, and also the ratio of graphite when cooled. With the use of molten metal, therefore, without the intermediate mixer, if the ladle containing an iron with high total carbon had to stand for some time before it could be used in the Siemens furnace, the metal would gradually cool down, thus lowering the carbon eutectic. It would become hyper-eutectic, and there would be a separation of the excess carbon as graphite or "kish." The "kish" would collect at the top of the ladle, and if it were charged into the furnace would first go into the slag and have to be got rid of before the bath could be properly worked. The time stated as necessary to pour "graphitic" iron into the furnace would confirm that view, otherwise the suggestion that graphite, rather than silicon, might cause slow working, was not borne out by observations he had had the opportunity of making. The use of a molten iron exceptionally high in total carbon would, of course, have the effect of increasing the total carbon in the bath, thus delaying the heat. It would be interesting if Mr. Thomas could say if he had experienced that separation of graphite in a mixer, as on the lines indicated it would appear that, if such were the case, it could only happen by working the mixer at a very low temperature. The statement that in iron obtained from one blast-furnace the silicon did not vary very much, although the graphite did, somewhat differed from his own experience, and hence he would be glad if Mr. Thomas would give further information. Generally speaking, the higher the silicon, the lower the total carbon, and usually also the lower the combined carbon when the iron was cold. The graphitic carbon was not necessarily the higher on cooling, although the graphite might be higher, depending upon the eutectic and the original temperature before commencing to cool. A number of cast analyses from the same furnace, working the same burden, gave a variation of graphitic carbon 0·35 per cent., but the silicon contents varied as much as 2 per cent.

Mr. F. W. PAUL (Harrogate) said that in the opening paragraph the author asserted it was necessary to have a proper quantity of slag during the melting stage in order to prevent the metal being over-oxidised and wasted. Of course it was well known that if the melting period was unduly prolonged extra waste of metal took place; but as to its being over-oxidised, he was of opinion that, irrespective of either quantity or quality of slag during the melting period, it was impossible to over-oxidise molten pig iron whilst it contained the bulk of its silicon, carbon, and manganese. The term “ over-oxidised ” used in reference to the end of a Bessemer blow, or the end of boiling stage of an open-hearth charge, would be quite intelligible. Mr. Thomas in the first paragraph, and also in the second paragraph (page 578), said that the metal during the melting stage was subject to being chilled unless covered with proper quantity of slag. He (Mr. Paul) would be glad if he would kindly explain how it was possible to get a chilling effect, without purposely lowering the temperature of the furnace by shutting off the gas, as the heat of the metal was solely derived from the combustion of the gas and air, and therefore the temperature of the furnace and metal was entirely under the control of the furnaceman. It was further said that, when working pig iron containing too high a percentage of silicon, the metal was liable to become too hot, but “ when working with pig iron containing the right percentage of silicon, the advantages were due to the greater initial heat in the metal.” That explanation appeared to be somewhat contradictory. With regard to pig iron containing a low percentage of silicon, viz., below 1·25 per cent., the author said “ the metal chills owing to scanty covering of slag, which results in longer time occupied in working, increased cost of fuel, labour, &c.” If instead of the three foregoing conditions, viz. (1) too high, (2) right, and (3) low, percentage of silicon, the equivalent of charges composed of pig iron mixed with steel scrap were considered, the composition of the initial charge would be :—

	Carbon. Per Cent.	Silicon. Per Cent.
(1) 100 per cent. pig iron	3·0	2·5
(2) 50 „ „ 50 per cent. steel scrap	1·75	1·25
(3) 25 „ „ 75 „ „	1·1	0·60

Perhaps the author would kindly explain why the troubles he referred to did not apply to Nos. 2 and 3. He (Mr. Paul) would say that, provided the composition of the charge was known beforehand, he had never found silicon such a delicate factor in determining the successful working of open-hearth process, and he would venture to think the shortcomings referred to by the author were more imaginary than real. As regarded the author's recommendation that "hæmatite pig iron containing not over 1¼ per cent. silicon could be with greater advantage worked in a basic-lined furnace," that would largely depend on whether it was supplied to the furnace in a molten state; but apart from that, he was of opinion it would not be a practical proposal in Great Britain, because pig iron makers would not undertake to supply at reasonable cost such iron with low percentage of sulpher. The novel suggestion of "working the acid process on a basic bottom," referred to in the third paragraph of page 579, with suggested addition of 3 to 5 per cent. lime, surely needed no laboured refutation. The consistency or fusibility of slag was an important feature in open-hearth process; it required to be decidedly acid in an acid furnace, or decidedly basic in a basic furnace, and any hovering on the border line would result in very thin or too fusible a slag, and the banks would be scoured out. It was with pleasure he referred to the most interesting part of the paper dealing with the retarding effect of graphitic carbon in the refining period, and as the result of the author's valuable experience in working with the Talbot process, he was of opinion that, in the ordinary open-hearth process, when working with high percentage of silicon, the longer time entailed was in reality due to the accompanying high percentage of graphite. He would beg to dissent from that view for the following reasons: with a high percentage of silicon in pig iron, assuming little steel scrap was used, it was essential that the silicon in the charge when melted should be eliminated before the furnaceman allowed the metal to get too hot. He could not do better than quote from some remarks on that subject in his own presidential address to the West of Scotland Iron and Steel Institution in 1897. "The greater relative affinity of silicon at low temperature for oxygen, as compared with carbon and iron, is cleverly exemplified in Sir Lowthian Bell's purifying process, which resulted in elimination of silicon whilst the carbon and iron are barely affected. I am of opinion the most objectionable feature of the open-hearth process is the elimination of the silicon, because its affinity is dependent on the temperature of the metal. The variation of the temperature of the metal may be due to the personal error of the man in charge, &c. It is this one feature of the process that I fear will cause practical difficulties in dealing successfully with 100-ton furnaces." It would appear that that anticipation of eight years before had been somewhat confirmed in the paper by Mr. Thomas. He had seen extreme cases of delay when a melter had allowed the metal to get too hot, and had not succeeded in getting the charge on the boil within nine hours after the charge was melted. All that was necessary to set matters right was to shut the gas off the furnace, and allow the metal to cool down; the affinity between oxygen and silicon was thereby restored, and on turning on the gas the charge of metal quickly came on a good brisk boil. That theory was also confirmed in the Bessemer process. With too high a percentage of silicon the blow was conducted at too high a temperature, under which conditions, when the carbon was all eliminated, there still remained as much as 1 per cent. of silicon unoxidised.

The author pointed out that frequently the whole bath of metal in the furnace was covered with a thick layer of kish. The writer was of opinion that the reducing effect of that carbon was one of the reasons of the delay in the reaction taking place, and was analogous to the delay which took place in ordinary open-hearth practice when anthracite coal was thrown into the bath of metal, which was a very effective means of prolonging or stopping the boil if for any reason it was found the charge would be worked down too soon. It seemed evident that until the kish was re-absorbed in the metal or burnt away, it would be unreasonable to expect an oxidising reaction to take place in the presence of so much carbon. Nature's laws were not yet so sufficiently well harnessed as to be able to yoke such opposite forces as oxidisation and reduction with the hope of making progress in either direction. As regarded the delay due to high percentage of silicon, he wished to point out that the *modus operandi* in the Talbot process was to top off about one half the charge of steel, so that the subsequent additions of molten pig iron were added to very hot steel and slag. As already pointed out, silicon had not much affinity for oxygen at that high temperature, and the delay in the Talbot process would appear to be comparable to the delay in getting a charge of high silicon pig iron on the boil in ordinary open-hearth practice when the furnaceman allowed the metal to get too hot.

Would the author be good enough to make the following experiment before the criticisms were published, with view of adding further data for consideration of that interesting subject, viz. that a quantity of kish previously collected, say 10 cwt., be added to the bath immediately before the addition of molten pig iron containing suitable low contents of graphite and silicon, with view of ascertaining what effect the kish *per se* has in retarding the refining period when good suitable molten iron is used.

In conclusion, he wished modestly to suggest, that in order to minimise the delay in the reaction when working with highly graphitic iron, which equally meant relatively high silicon, that it might be found an advantage in the Talbot process to shut the gas off the furnace after tapping. By so doing the bath of steel and slag would cool to such a temperature as would permit of the more ready affinity of the silicon and the oxides in the molten slag. After adding the fresh addition of molten pig iron, the floating kish on the surface of the bath would also be more quickly burnt if air without gas were permitted to traverse the surface. It would be a matter of experiment as to whether longer time was necessary to regain the necessary tapping temperature other than what would be gained during the normal boiling period.

Mr. A. W. Richards (Grangetown) wrote that the author laid considerable stress on the difficulties he had met with owing to varying amounts of silicon in the iron from the blast-furnaces. He said nothing, however, as to the amount of scrap he had used with the low silicon iron mostly complained about. The cause of the cutting of the banks of the open-hearth furnace had most probably been *not* through using low silicon iron, but owing to trying to use too much soft scrap with it. The author made an excellent suggestion, viz.: that low silicon acid iron should be melted on a basic hearth. That process was brought to a successful issue, in Scotland, by Mr. James Riley, Vice-President of the Iron and Steel Institute. Recognising its value, it had been worked at the works of Messrs. Bolckow, Vaughan & Company with unqualified success for over twelve years. With regard to the difficulties described by the author with graphite, they were more likely caused by getting a cast of very grey iron containing high silicon, which used up most of the oxygen in the oxides present in the furnace, and when the time arrived for the carbon to be oxidised there was very little oxygen left. It was very difficult to work any liquid process without a mixer, and if there had been one in the works where the author had apparently gained his experience, few of the troubles mentioned by him would have been encountered.

Mr. E. H. **Saniter** (Rotherham) wrote that the value of Mr. Thomas' paper would have been greatly increased if complete analyses illustrating the difference between what was called high graphitic and low graphitic iron had been included. In the absence of such analyses it was somewhat difficult to discuss the questions raised. As was well known, Nos. 1, 2, and 3 hæmatite, although they varied in graphite, always contained from 2½ to 3 per cent. Of course such iron would contain more carbon, silicon, and manganese than a forge iron, and would naturally work differently. It seemed extraordinary that with a highly oxidising slag and a highly oxidising atmosphere graphite should float about on the slag as stated. It also seemed extraordinary that, when 50 tons of grey iron were added to 100 tons of soft steel at a high temperature, the whole of the carbon should not immediately become combined. If the highly graphitic iron contained more silicon and manganese, it would naturally retard the boil, and would at the same time superheat the bath, and so cause the delayed boil to be violent as described.

Mr. J. E. **Stead**, F.R.S., Member of Council, wrote that it would appear that Mr. Thomas was of opinion that the carbon condition was different in fluid grey iron from what it was in fluid white iron, and that in the latter the carbon was in the combined condition, whilst in the former it was as graphite. He explained the retardation of the reaction in the Talbot process, when "kishy" iron was used, to the assumed difference in the carbon condition, and considered that when a small quantity of such iron was mixed with a large proportion of fluid carbonless iron, the carbon in the mixture, although not more than 1 per cent., was still in the graphitic condition. It was difficult to see how that could be. Had the author made any attempt to prove whether or not such were the case? It would be of great value to metallurgists if Mr. Thomas would kindly give analyses of the white iron which rapidly produced a boil, and of the grey iron which did not. Usually grey iron contained a larger percentage of silicon and manganese than white iron, and it seemed natural to believe that the retardation was caused mainly by these elements, and not by difference in the carbon condition. It was probable that if, to a charge of white iron run into the Talbot furnace, some fluid silicon pig were first added, the reaction would be delayed until the silicon was nearly all oxidised. The explosive violence of the delayed reaction when grey iron was used might be partly explained by the fact that the free graphite, which at first floated on the surface of the bath, would get mixed with the ferruginous cinder as soon as the boil commenced, and that would cause a great evolution of carbonic oxide gas. He hoped that Mr. Thomas would continue his researches, and obtain data sufficient to enable the phenomena, which at present were apparently involved in mystery, to be explained.

Mr. A. S. **Thomas**, in reply to Mr. E. Adamson and Mr. F. W. Paul, wrote that experience had taught that 3·5 per cent. of lime would be sufficient to work low silicon hæmatite iron on a basic bottom, provided molten iron, or pig iron which was cast in chills and not in the usual sand beds, were used. The average quantity of lime used over a considerable period was only 4 per cent., the iron used averaging 1 per cent. silicon. His firm were daily making grey iron containing 3 to 3½ per cent. graphitic carbon, 1 per cent. silicon, with ·03 to ·05 sulphur. By making such iron, the output of the blast-furnaces had increased 25 per cent., so that he failed to see that the iron cost more than the usual high silicon iron made. In fact it should, and he believed did, cost considerably less, owing to the larger output possible and lower fuel consumption; as when working low silicon iron, a larger proportion of ore could be carried per unit of fuel. Mr. Sahlin, in a very admirable paper read before the Institute a few years ago, pointed out the great advantage to the British ironmaster in making that class of iron. With regard to the term "chilled," the word was used in a relative sense. The heat obtained from the combustion of the gas and air was not absorbed and retained by the metal when coated with a slag high in ferrous oxide, which was a thin slag, to the same extent as when coated with a suitable slag. Also, the metal, although not "over-oxidised," was certainly excessively oxidised. It referred to the use of low silicon pig iron (under 1¼ per cent.), with the addition of 40 per cent. soft scrap; thus the suggestion of working the iron on a basic bottom and the addition of a still greater percentage of steel scrap, without any fear of damaging the banks or bottom. He thought it possible Mr. Paul had misunderstood his meaning of over-oxidisation. His reference was to the excessive oxidation of the metal when melting, not to an over-oxidised bath. The fact that low silicon hæmatite iron had been successfully worked on a basic bottom for over twelve years at the works of Messrs. Bolckow, Vaughan, & Company certainly showed that the idea was far from novel. Mr. A. W. Richards suggested that it was not the low silicon but the great amount of soft steel scrap which might be used which caused trouble. By using a greater amount of pig iron and less scrap, another evil was experienced, viz. introducing relatively a much greater quantity of carbon, and especially in the form of graphite. The remedy he ventured to suggest was to work the low silicon iron on a basic bottom. More scrap could be used, and the difficulties met with, in putting the metal on the boil and boiling down, would be done away with. Certainly not more than 5 per cent. of lime would be required. This he knew by experience. Regarding graphite, Mr. Paul was wrong in assuming that the trouble was not high graphite but high silicon, and suggesting that "when working with highly graphitic iron, which equally meant relatively high silicon," that the temperature of the bath of steel and slag be lowered after tapping. In the first place, he wished to point out that high graphite did not necessarily mean high silicon, as iron was being made daily with high graphite and low silicon contents. It was true, however, that high silicon was generally accompanied by high graphite. After tapping, the temperature of the bath was low enough, for gas was taken off to some extent to enable the men to fettle the furnace banks. Also, before the molten iron was poured into the furnace, a large quantity of oxides and lime were added (usually about 10 tons), which greatly reduced the temperature. It was not therefore likely, or even possible, that the bath, after those additions, would be "too hot." The average percentage of silicon in the iron used was 1 per cent. Fifty tons of that iron poured into 100 tons of molten steel could not be said to make the bath contain a high percentage of silicon. All practical steel melters knew that when using very highly siliceous iron, the silicon would not be eliminated unless the temperature of the bath of metal was lowered. He had used iron with 3 to 4 per cent. silicon, but had never taken more than two hours to put the metal on the boil. The melter mentioned by Mr. Paul as not being able to get the metal on the boil for nine hours after melting, certainly did not know his work. If he had thrown steel scrap into the bath, and slacked the air and gas off the furnace, the metal would have boiled within three hours after melting. The iron which reacted freely with the oxides contained carbon practically all in the combined state, while with iron containing about 3½ per cent. of carbon in the graphitic form, and with a low percentage of silicon (1 per cent. and under), the difficulties referred to were experienced.

Referring to Mr. Paul's suggested experiment of charging "kish" with low silicon iron to demonstrate that it was not the high silicon which he suspected of causing the trouble, there was no necessity for such an experiment, as it was frequently done whenever the low silicon highly graphitic iron above mentioned was charged.

At the meeting of the American Institute of Mining Engineers a large number of papers were read by title, the list including the first part of an exhaustive paper on piping and segregation in steel ingots by Professor H. M. Howe, advance copies of which were unfortunately not completed in time for the meeting. The following papers were also taken as read:—

METHODS OF MINING, HAULING, AND SCREENING AT THE MINES OF THE ALDRICH MINING COMPANY AT BRILLIANT, ALABAMA.

BY T. H. ALDRICH, JUNR. (BIRMINGHAM, ALA.).

[*Abstract.*]

THE Aldrich Mining Company holds under lease from the Illinois Central Railroad Company about 14,000 acres, in the East half of Township 12, Range 12 W., in Marion county, Alabama, and owns other lands, of which about 1000 acres adjoin this leased track, making a total area of about 15,000 acres, all of which is underlain by the coal-seam upon which the company is operating. This seam is nearly horizontal; and a ravine, diagonally crossing the tract, exposes the outcrop on either side for about two miles. The territory has been so divided that nearly the whole of it can be worked out by two collieries. The mines at Brilliant were opened in the Fall of 1898, and shipments began in the following spring, the original plan being to furnish steam-coal for locomotives to the Illinois Central Railroad Company. The field was entirely new; and the softness of the coal at the outcrop induced the belief that it could be very cheaply mined. But with the advance of the entries to increasing distances from the outcrop, the coal proved so hard that it could no longer be drilled with a breast-auger; and the expense of mining became very heavy. On the other hand, since no other deposit of such excellent coal was known to exist on the line of the Illinois Central, or any other railroad available as customer or carrier, and since the tract controlled by the Aldrich Mining Company could furnish for a hundred years a large annual tonnage, it was obviously worth while to make extensive experiments, in order to perfect a system of mining, haulage, dumping, &c., which would effect the minimum cost of production. The coal-seam was only 30 inches thick, and almost horizontal in position. It presented no "butts" or "faces," and the coal

was so tight between the top and bottom that it could not be shot "from the solid." There were no partings or soft streaks whatever. The roof was sometimes sandstone and sometimes slate, usually stratified sandstone. The bottom was fire-clay for about 4 inches; then gritty clay for 10 inches; then sandstone. The long-wall system was tried, using hand-labour with picks. This worked well.

Under-cutting with compressed air machines was the only really successful method.

The coal-cutting machines are run by compressed air, although electric power is used for haulage. Undoubtedly a large further saving could be effected by the use of electrically-transmitted power for coal-cutting, which would eliminate the serious cost of purchasing, laying, maintaining, repairing and renewing pipes, hose, hose-fittings and valves, besides reducing the items of fuel and power-house expenses. In so small a seam, the amount of coal won for a given amount of cutting is relatively small; that of pipe-laying per ton is correspondingly large, the distance to be covered with pipes increasing very rapidly; and the pipe remaining permanently in the mine, practically never to be recovered, represents in all $10,000 per 75,000 tons of coal mined. The mining is done by contract, each contractor receiving one machine and one entry, and delivering the coal on a large wagon. Under this system, it was found that twice as many rooms and nearly twice as many men were required for a given output, and that this output was very irregular. On some days all the rooms would be only partly cleaned, so that none were ready for the machine. On other days all the rooms would be ready simultaneously, while, of course, the machine was not available for all at once. It was impossible to get the men to clean up the rooms so that they could be made ready for the machine in regular succession; and consequently they were continually wrangling for precedence in this respect. Under these conditions, the output of coal per machine was on one day 30 tons; on the next, perhaps, nothing; and the average was not much more than 15 tons.

Several systems of hauling were tried. The old Welsh system of trucks, delivering the coal to cars, was finally adopted, with a type of truck made with two rib-irons, four trunnion-wheels on the sides of the irons, and five pieces of plank, with no draw-bars, bumpers, or end-gates. (Later, end-gates were adopted, consisting of a plank lifting out between two guides, similar to the tail-gate of a cart.) These trucks, which were used in the rooms only, had 14-inch wheels, were very light and cheap, could be pushed easily, and were hung so low that the bottom was on a level with the top of the rail, and the miner could load the largest lumps over the sides or ends, without laboriously building up the load.

At the mouth of the room-neck, one "brushing-shot," tearing down 3 feet, is made, and, when the trucks have been pushed to this point, the coal is transferred with a shovel from the trucks to large wagons in the entry, holding 3 tons each, and having solid ends. The main entry is laid with 25-lb. rails, with splice-bars and bonds; there are no room-neck switches; no coal is spilled in the roadway; no cleaning of track is necessary; and the hauling is done entirely by electric power, mules being dispensed with altogether. The advantages of this system of trucks, combined with large wagons and electric haulage, are as follows: 1. The absence of switches makes pipe-laying easy. Sometimes an entry will go 0·25 mile without encountering water, and suddenly there will be so much water in one place that a suction-pipe or a pump must be installed. Under the old system this pipe might have to go under a dozen switches, at great trouble and expense. 2. No top is taken down and no bottom is taken up in the rooms, since the truck follows the seam. Besides receiving more per ton, the loaders load more tons per day. They never have to wait for wagons. The large wagons spill no coal on roadways. The cost of the maintenance of wagons is smaller, as is also the number of wagons required. 3. The smooth main track permits of high speed, thus giving the motor greater range of action, and securing a greater utilisation of gangways and tracks, in proportion to the repairs inevitably required by lapse of time. 4. Drivers and mules are eliminated. 5. Many fixed charges and contingent expenses, such as mule-feed in time of strike or shut-down, are greatly reduced. 6. Per ton of capacity, the investment in wagons is much smaller. 7. By reason of the superior design of the present wagons, the cost of maintenance per wagon is no greater than before; and, since the number of large wagons per ton of coal mined is much smaller, the actual expense of this item per ton is only one-fifteenth of what it used to be. 8. The system requires no additional excavation.

The wheels of mine-wagons are subjected to exceptionally severe wear and rough usage. The wagons, having neither buffers nor brakes, are jammed together or jerked apart in hauling, or violently checked by "spragging"; the roads are not kept in perfect condition or repaired oftener than is absolutely necessary, and the wheels are consequently jolted over irregularities and bad joints, or thrown off the rails by unnoticed obstacles, and rudely jerked on again. The wheel adopted is a solid casting, having no parts (except the oil-plugs) which can be loosened or detached. The leading purposes of the design are to secure maximum strength for the weight of metal; uniform wear of parts; and facility and certainty of lubrication. 1. By plates, bracing the sides of the rim, a proportional strength, greater than that of wheels with spokes, is secured. Spragging may be provided for by means of a wedge-shaped lug in either web, with a hook, adapted to catch and hold the wheel. 2. Uniform wear, essential to durability, is secured by an equal distribution of strain upon the bearing, and of lubricant upon the surface exposed to friction. The equal strain is obtained by means of a hub presenting an integral bearing-surface, bisected by a vertical longitudinal plane through the centre of the tread of the wheel. The pressure per square inch is, therefore, the same at all points of the bearing-surface; and the wheel moves in true alignment with the direction of motion of the wagon, until it is completely worn out. 3. For the purpose of lubrication the wheel is cast with webs, enclosing a large oil-chamber, which extends from hub to rim, and is so large that three, or at most four, oilings per year will be sufficient. When so great a quantity of lubricant is provided, a method of feeding is obviously required which, while not liable to clog, will supply no more oil than is necessary, and will evenly distribute this supply. This is effected by one or more entirely open and unobstructed longitudinal openings or slots in the hub, leading directly from the reservoir to the axle, and so proportioned as to catch, as the wheel revolves, a suitable amount of the film of oil on the sides of the reservoir, and feed it to the centre of the bearing-surface. When packing or waste is placed over or in the oil-ducts, they are liable to become clogged; and this liability calls for that closer attention to the wheel which it is desirable to render unnecessary. The wheel here described has demonstrated, by long continuous use, the superior durability, evenness of wear, and freedom from the necessity of attention above claimed.

The couplings of the large wagons employed in this system of haulage are so designed as to permit at the tipple the tilting of each wagon, without breaking its connection with the preceding or the following wagon, and thus the connection of the train with the motor which pulls it. This problem is not difficult. It was solved by using, for the large wagons, couplings consisting of three links and an eye-bolt, which is held on with jam-nuts, and the shank of which passes through the upturned end of the draw-bar. The other end of the draw-bar is a hook; and the eye-bolt acts as a swivel. The tipple is a cylindrical frame, rotating on trunnion-wheels, and so arranged as to permit the weighing and tipping of each wagon of a mine-train, without breaking the train or disconnecting the motor, and in such a manner that one man only is employed on the tipple, he attending to both weighing and tipping.

As already remarked, the most advantageous size for lump-coal has been found to be that of a 2-inch round hole in the screen. The screens upon which the coal is dumped have, therefore, holes of this size.

Two systems of disposing of the smaller coal passing these screens are now in use:

1. Under the first system, used at Mine No. 1, this coal is run over a screen having 0·75-inch round holes; the over-size is sold as "nut"; and the under-size, after washing in a simple trough washer.

2. Under the second system, used at Mine No. 2, all the small coal (under 2 inches diameter) is elevated and washed in jigs. The jigging is extremely simple, because there is no dirt

sticking to the coal. The seam has no partings, and is absolutely clean coal from top to bottom, so that, apart from the usual slate broken from the top, the only foreign matter is fine, hard fireclay, separated from the floor by the picks of the under-cutting machine. This fireclay, however small in amount, is extremely objectionable, and, unless removed by washing, ruins the coal. The total weight of all impurities thus removed is about equal to the weight of the moisture in the cleaned product, so that the jigs practically furnish, by weight, as much saleable coal as they receive of crude material. This product is sold without further sizing.

Against the second system must be charged a slight increase in the cost of washing, due to the difference between operation, maintenance, &c., of the jig and trough-washer plants. This is a very small item and, from the data available, cannot be figured.

A SIMPLE ROTARY DISTRIBUTOR FOR BLAST-FURNACE CHARGES.

BY DAVID BAKER (PHILADELPHIA, PA.).

[*Abstract.*]

IN a paper presented to the American Institute of Mining Engineers, September 1904, the author showed the great fault of mechanical charging devices to be that the materials charged by the dumping of the skip were separated, the coarse materials having high velocity, and the fine, low—thus giving paths of low resistance through the stock in the furnace, which resulted in unequal distribution of the furnace gases, unequal reduction, slips, scaffolds, irregular cutting of the inwall, "off" iron, and increased fuel consumption.

Since the presentation of that paper, he has designed a very simple form of rotary distributor, which may be applied to any form of double-bell charger, retaining the perfect gas-seal, which is so admirably obtained by that construction.

An application for a patent having the same construction was filed in the United States shortly afterwards, his own, by Mr. Albrecht B. Neumann, of Chicago, Ill. A joint ownership of the invention was the result; and the apparatus has received the name of the Baker and Neumann distributor.

Fig. 1 shows the top of a modern skip-filled furnace, provided with a main bell, closing the mouth of the furnace, and a gas-seal bell above, closing the gas-seal. It will be noticed that this small bell, which in ordinary construction permits a discharge of the materials all around its periphery, is here provided with a deflector plate that causes the material to discharge only around one-half of its circumference, when the bell is lowered. The dotted lines show the position of the distributing-bell and plate when the load is discharged.

Rotation is given to the bell and plate during its upward movement to close, by the ratchet lever (A) which drives the bevel gear (B) through which the hollow rod (C) passes, but to which it is rotatably connected by two wings or feathers, projecting from opposite sides of the hollow bell-hanger and travelling in corresponding grooves in the hub of the bevel gear (B)

Fig. 2 is an enlarged view of the upper end of the hollow distributing-bell hanger, the crosshead connection to the bell-operating beam and the bevel-gear driver, showing also the ratchet lever (A) and its method of attachment to the bell-operating lever with the connection of the indicator-rod leading to the ground.

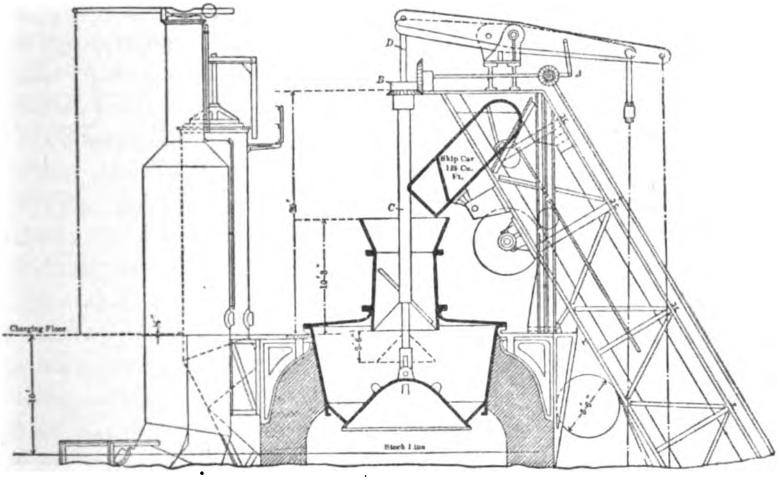

FIG. 1.—Top of a Modern Skip-filled Furnace.

By drilling holes where required, the ratchet lever may be provided with several points of attachment to the bell-beam, and the revolution of the distributor set at any angle desired. The ratchet permits the lowering of the distributing-bell without imparting any turning movement to the plate and bell; but during the closing of this bell, when it is without any load, the rotation is made.

When the whole charge is hoisted, the distributing-bell is set to rotate at each discharge in such a manner as to cause the centre points of each discharge of the distributing-bell to rotate a definite distance for each charge from the position of the preceding charge. The overlapping corrects the sorting which may have been made in any one charge.

The author prefers to hoist the charge in eight skips and give a 91° movement to the distributor.

At the present writing, seven furnaces have been equipped with this device, the first one having been installed a little over a year ago. The mechanical part of the arrangement has given no trouble whatever. A door is provided, however, in the receiving-hopper, through which, by means of a steel bar and sledge, the plate may be cut loose in a few minutes, and dropped into the furnace. Fortunately this safeguard has never been needed. The work of the three furnaces in which the device was first installed, compared with their previous record, shows an average saving in fuel of 5·4 per cent., an increase in production of 21·6 per cent., a large reduction in the flue-dust thrown off, and a great increase in regularity of running.

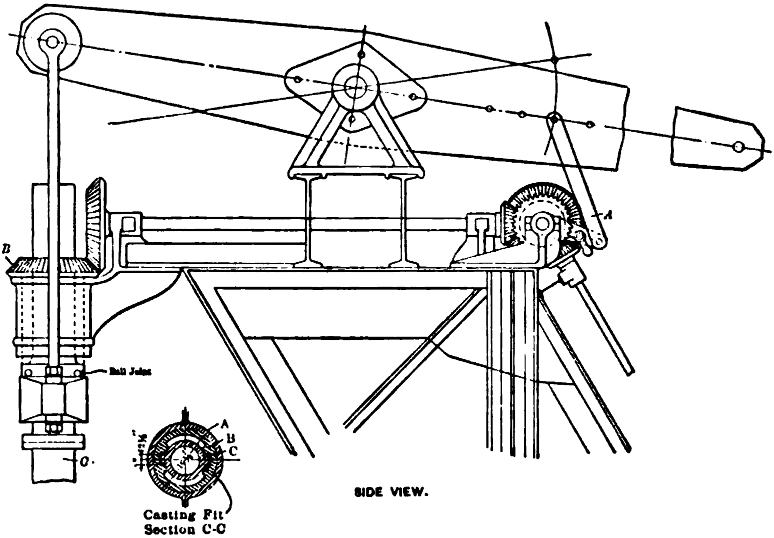

FIG. 2.—Enlarged View of Ratchet Lever.

HEAT-TREATMENT OF STEELS CONTAINING 0·50 AND 0·80 PER CENT. OF CARBON.

By C. E. CORSON (Latrobe, Pa.).

[*Abstract.*]

I. Introduction.

The experiments detailed in this paper do not claim to constitute more than a contribution to the general subject. The material used was acid open-hearth steel, containing from 0·50 to 0·80 per cent. of carbon, with a nearly uniform percentage of other elements, and the investigation was directed to the following points:—Steel containing about 0·50 per cent. of carbon: 1. The structure as related to the temperature at the same rate of cooling; 2. The structure and physical properties as related to temperature at different rates of cooling; 3. The structure and physical properties as related to different finishing-temperatures and different rates of cooling; 4. The bearing of these observations upon the statement of Professor Albert Sauveur * that hot work, as such, has no influence upon the structure of the metal.

Steel containing about 0·75 per cent. of carbon: 1. Physical properties, as related to temperature at different rates of cooling; 2. Physical properties, as related to different finishing-temperatures and different rates of cooling; 3. The bearing of these observations upon the statements of Professor H. M. Howe † that the tensile strength at first increases with the intensity of the hardening, but reaches a maximum and then declines. In the case of high-carbon steel, a moderate rapidity of cooling may give the highest tensile strength.

The temperatures were determined by a Le Chatelier pyrometer, and in the first series of experiments on the structure of acid open-hearth steel containing about 0·50 per cent. of carbon, as related to temperature at the same rate of cooling. the composition of the steel was: C., 0·55; P., 0·045; Mn., 0·66; Si., 0·25; and S., 0·032 per cent. The steel was heated in a gas furnace to various temperatures, and immediately cooled in the air, without being held at the temperature reached. The Ac of this steel was proved to be at 710° C.

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* *The Metallographist*, vol. ii. p. 267.

† *Iron, Steel, and Other Alloys*, Boston, 1903, p. 221.

The chief point brought out by a study of this series is that until the heating has been carried past the critical point there is no change in structure; the previous crystallisation has not been broken up. But as soon as this point has been passed in the heating process, a great change takes place, and there is a new state of crystallisation. After passing through Ac, the steel has become a solid solution, and when the cooling period begins, this point governs the size of the crystals; the higher the point Ac, the coarser will be the structure. In this experiment, bars 9 inches long by 1·25 inches square were used, and the rate of cooling was therefore relatively rapid. Consequently the various temperatures to which the steel was heated do not show marked differences, because the rapidity in cooling tends to destroy the effect of heating to a high temperature.

In the experiments as to the structure and physical tests as related to temperature at different rates of cooling on steel, the composition was: C., 0·50; P., 0·042; Mn., 0·65; Si., 0·24; S., 0·029 per cent.; and the critical point Ac was 710° C.

The air-cooled specimens exhibit a relatively finer structure than those cooled more slowly. The ferrite network is less defined because it has been absorbed by the pearlite, in the form of sorbite. As the rate of cooling is increased by the use of ashes or lime, the ferrite separates out more completely, and has a well-defined network, as the pearlite becomes more a lamellar combination of iron carbide and iron.

As the rate of cooling has been increased, or, in other words, as the steel has been made softer, the tensile strength has declined, while the elongation has increased.

This illustrates the effect of the development of ferrite upon the tensile strength. As the ferrite has more completely separated out and become a well-defined network, it has softened the steel, thereby decreasing tensile strength and increasing the stretch.

To investigate the structure and physical properties as related to different finishing-temperatures and different rates of cooling, a steel containing: C., 0·52; P., 0·034; Mn., 0·65; Si., 0·24; and S., 0·029 per cent. was selected. Bars 12 inches long by 1·25 inches square were drawn from the test-ingots, 4 inches square, which had been previously cogged under a steam-hammer, all these ingots having been heated to 1000° C. (the temperature of the furnace) before work was begun. Since the finished bars were so small in section that cooling would be, in any case, comparatively rapid, only two rates of cooling were tried, namely, that of cooling in lime and that of cooling in air within a lined box, which simply protected the bar from drafts of air in the shop. The temperature in this box was about 100° F.

The work was measured by time, since the smith hammered the bars under a small steam-hammer, giving about the same blows to each bar, without any knowledge of what the experimenter had in mind.

As in the preceding group, the effect of the lime treatment, allowing a thorough separation of the ferrite from the mother metal, lowered in every case the tensile strength, so, conversely, by cooling at a quicker rate in the box, the tensile strength was raised. The difference became greater as the cooling period was lengthened by higher finishing temperature, as indicated by the smaller amount of work done upon the bar before cooling. This marked decrease was not, however, maintained in all the samples. There has been a notion at some steelworks that, the hotter a bar is finished, the lower will be its tensile strength. These experiments disprove that proposition, confirming, so far as they go, the well-established theory that tensile strength increases, up to a certain point, with finishing temperature. Beyond that point (which, however, was not pasesd) it decreases.

To test Professor Sauveur's statement, quoted above, two bars were drawn from the ingot, the first in the usual way (the work occupying about two minutes), and cooled in the air. When cold, it was re-heated in a coke-furnace to cherry-red;

and at the same time the second bar was hammered from the hot ingot until it was cherry-red (about 1350° F.). When work ceased on this bar, the other was drawn from the furnace. Even to the experienced eye of a heater, there was no difference in appearance; both seemed to have the same temperature. They were then cooled, side by side, in a lined box. The structure of the bar re-heated to cherry-red was finer, showing that the identical outside appearance of the two bars was misleading as to their internal condition. The centre of the worked bar was higher than that of the re-heated one. It is not possible to produce the same effect by work as by re-heating; for work preserves (and, if it be severe enough, even raises) the internal temperature, and subsequent cooling sets up an unequal crystallisation. Under proper re-heating, on the other hand, the steel becomes a solid solution, from which crystals of approximate homogeneity and uniform size may separate.

The physical tests of these bars corresponded to the structure, so that while Professor Sauveur's statement may be approximately correct for a very small section, the discrepancy of internal conditions which invalidates his proposition becomes greater as the metallic mass treated is increased.

In the experiments with acid open-hearth steel containing about 0·75 per cent. of carbon, it may be assumed that the structural changes are analogous to those produced by the same treatment in 0·50 = carbon steel.

The physical properties as related to temperature at different rates of cooling of a steel containing C., 0·72; P., 0·034; Mn., 0·64; Si., 0·22; S., 0·03, were not as regular or as conclusive as those obtained from the 0·50 per cent. carbon steel; but it appears upon careful study that as the rate of cooling increases the tensile strength and the contraction decrease, while there is a slight rise in elongation. Although, as already explained, the experiments were made upon bars 1·25 inches square, and therefore can serve only as indications of what would take place in larger masses, it has been found in practical experience that these indications are highly trustworthy, and that the behaviour of large masses of steel under similar conditions follows the same law.

The statement of Professor Howe, quoted on a preceding page, is confirmed by the experiments. There was clearly an increase of tensile strength with increase of finishing temperature.

The experiments have shown that, with one exception, the theories based by investigators of acknowledged authority upon experiments with other grades of steel hold good as to the two classes of acid open-hearth steel here considered. Indeed, with regard to the one exception—namely, the qualified contradiction of Professor Sauveur's statement as to the relative effect upon structure of mechanical work and heat treatment—it may fairly be claimed that while the observations adduced as evidence were made upon a certain kind of steel only, the explanation which they demand is equally applicable to all other kinds, so far as their structure is affected by work or by heat treatment. In this particular, the experiments simply declare what we would naturally expect, as an inference from the physical circumstances.

It may therefore be confessed that these experiments have done no more than bring certain commercial steels into line with others, more thoroughly investigated heretofore, in support of generally accepted theories as to heat treatment. In actual practice, the results of the above experiments, and others like them, have, however, proved highly useful as checks upon daily operations, guides to needed improvements in manipulation, and suggestions of remedy for difficulties encountered.

INTERNAL STRESSES AND STRAINS IN IRON AND STEEL.

By HENRY D. HIBBARD (Plainfield, N.J.).

[*Abstract.*]

For the purpose of this paper, internal strains in iron and steel may be divided into two classes, according to the causes which produce them, viz.:—

1. Those caused by an irregular rate of change in temperature, that is, of heating or cooling.

2. Those caused by cold-working or permanent change of shape of the piece under consideration by mechanical means at atmospheric temperatures, or at least at temperatures below that at which the metal is softened.

The first class of internal strains is by far the more important of the two. The rate of change of temperature may act in a purely physical manner in producing strains; or, when it comprises quenching a piece of steel from a high temperature, it may have also a chemical effect on the metal. The amount of change in temperature does not, however, affect the strains produced. The rate determines all.

Strains due to irregular cooling should be considered under two aspects. (1) Those which arise during the continuance of the causes which produce them—that is, temporary strains; and (2) those which remain after their causes have ceased to act—that is, permanent strains. Temporary strains in many cases become permanent, especially when set up during cooling at an irregular rate. The phenomena of permanent strains are, during their formation, the same as of temporary strains.

The following cases will illustrate the two ways in which each kind of strain may result in rupture of the piece. When an ingot of hard steel is placed in a red-hot furnace, and is so ruptured internally by the faster expansion of the exterior, due to the rapid heating it undergoes, that it separates into pieces when forged or rolled, its ruin was caused by strains occurring while the cause—namely, the quick heating—was in operation. This is a typical example of temporary strains in steel. When a boiler-plate of soft steel, lying cold on the floor of the shop, cracks suddenly, it is because of strains existing after their cause had ceased its action. This is the usual kind of internal strains occurring in iron and steel, and is the kind chiefly meant in what follows in this part; it is an example of permanent strain. These two instances cited are, it will be understood, extreme cases, in which the piece is ruptured by the intensity of the strains.

The intensity of the strains considered in this part depends on the following determining factors:—

1. The rate of change of temperature; 2. The shape of the piece; 3. The bulk or volume of the piece; 4. The elastic limit of the metal; 5. The ductility of the metal; 6. The coefficient of expansion of the metal.

The rate of change of temperature is the great governing condition producing or reducing internal strains both temporary and permanent. The faster the rate, the greater the strains. The amount of change, however great, is unimportant in this connection if the rate be sufficiently slow. The rate depends on the difference between the temperature of the piece of metal and that of its environment, and on the heat-conductivity of the metal. The greater the difference in the temperatures mentioned, the greater the strains resulting, and the greater the heat-conductivity, the less the strains. A poor heat-conductor, like manganese steel, must, if of massive form, be heated very slowly if dangerous strains are to be avoided.

Extreme cases in which the rates of change of temperature are the greatest met with in the practical manipulation of iron and steel are: for rising temperature, when the article is placed cold within the hot heating-chamber of a furnace, and for lowering temperature, when it is taken heated from a furnace and plunged into a cooling bath.

With certain exceptions, any change in temperature up or down below the degree of heat at which it softens, produces in a piece of iron a somewhat irregular rate of heating or cooling, and hence strains.

To avoid danger to the piece from this cause, less difference must be maintained between the temperature of the article and that of its environment. If the dangerous strains arise in heating the article, it must be heated more slowly. The heating-chamber or receptacle must not be too much hotter than the article placed therein. In extreme cases the chamber and the article must be slowly heated together, this procedure being called for, however, only in the heating of bulky articles of very hard iron or steel.

Many steel castings may not be allowed to cool in the open, or even in the sand, without danger of spontaneous rupture from internal strains, but must be placed while still hot in a heated receptacle, usually a furnace, and allowed to cool with the furnace at a much slower rate than if in the open air. Steel wheels, as well as the iron car-wheels, usually require such treatment, though the ductility of the softer grades may admit of its omission. On the other hand, the greater coefficient of expansion of steel tends to set up greater strains than those of the iron wheels.

When a piece of iron or steel containing intense strains is heated in one part gently—it may be to 200° or 300° F.—the strains are changed so that when the piece is cold it is not exactly of the same shape as before. It may not be possible to determine this fact by measurement, but it may be made apparent by the fit of two such pieces together before and after one of them has had its strains changed by the partial heating.

The shape of the piece of metal affects strains very greatly when it is heated or cooled. If it be made up of relatively thick and thin parts continuously connected to each other, such as the thin web and thick hub and rim of a car-wheel, on changing its temperature strains will be set up within it, not only between the interior and surface portions but between the thick and thin parts as a whole. In the case cited of a cast car-wheel, these latter strains are those which are dangerous, causing the breakage and consequent destruction of the usefulness of the wheel if they be allowed to develop to their fullest extent by allowing the wheel to follow its own rate of cooling in the open. So, for a given change in temperature, the shape of the piece is very important in determining the degree of strains it possesses. Large plane surfaces tend to intensify strains due to change of temperature of a piece of iron or steel either from heating, cooling from a high or casting temperature, or quenching.

The bulk of the piece of metal has great influence on its strains when its temperature is changed because of the distance which heat must be conducted between the surface and interior parts. When the bulk and therefore this distance is relatively great, the strains are great in proportion, and when the bulk is small they are less. High conductivity of heat tends to offset great bulk in the strains resulting from a change in temperature. There are, however, many ways in which the use of holes and recesses within the contour of the article may so reduce the bulk that without detriment to its use the thickness may be brought within safe limits to admit of it being cooled from a high heat in a cooling bath without being in danger of cracking from the internal strains set up.

When an article of iron or steel is liable to crack in service from strains, the danger is sometimes best avoided by making it in two or more pieces. Thus a cast-iron bottom-plate, on the centre of which was cast a large ingot of steel, was broken the first time used by the expansion of the central part heated by the molten steel. On making a plate for the purpose, of four pieces bolted together, no further trouble from this cause resulted.

The elastic limit of the metal affects the intensity of the strains, because when it is low it may allow the metal to yield under the stresses which cause strains so as to relieve them in part.

Ductility of iron or steel sometimes allows it to yield without fracture under stresses of sufficient magnitude, so that the strains are in some degree lessened. A highly ductile metal rarely or never breaks from internal strains unless extremely massive. When, as in cast iron and hardened high-carbon steel, there is no ductility, and the elastic limit coincides with the ultimate strength, the strains set up in cooling cannot be relieved, and may easily reach an intensity which will cause the piece to crack or break.

The coefficient of expansion, strictly speaking, wholly determines the intensity of the strains arising from irregular rates of change of temperature in metals, for if it became zero such strains would not occur. The greater the rate of expansion the more intense become the strains arising from a given rate of change in temperature.

When a cold massive piece of steel, as an ingot, is to be heated in a furnace, it is a matter of importance to know whether its previous cooling was rapid or slow. If rapid, it may contain so much strain as to be ruptured internally by the heating operation, while if it has been slowly cooled it may, because of smaller internal strains, endure that operation safely. To reduce strains in ingots which are to be cooled to the atmospheric temperature, the rate of cooling should be retarded.

Strains due to cold-working iron or steel are the result of molecular displacement and very likely of mere changes in the inter-molecular spaces. The phenomena occurring with these strains include higher tensile strength, higher elastic limit, greater hardness, less ductility, and lower specific gravity. Perhaps it is not claiming too much to say that these modified properties are the direct result of the strains, as, if the strains be destroyed by heating to redness, all these modifications disappear with them and the properties of the metal are substantially those it possessed before the cold-working operation was performed upon it. For the purposes of this paper, therefore, these modified properties may be considered as the result of the strains.

Strains are an unavoidable accompaniment of cold-working iron and steel. Those due to cold-rolling or wire-drawing purposely applied have often useful effects when properly taken advantage of, while harmful or undesirable effects may be avoided by reducing them by annealing or other proper heat-treatment. When the pieces of metal so cold-worked are not large and the ductility considerable there is no danger of spontaneous rupture. The cold-working may, indeed, be continued so as to cause dangerous strains if they be not relieved by heating. The service of larger pieces may be such that they are subjected to cold-working, as in the case of a die ring for a centrifugal ore-grinding machine, which will cause flow of the metal with resulting strains, and may distort the piece or even tear it apart or break it.

The beneficial effects of strains due to cold-working come from the higher tensile strength and elastic limit of the metal. Drawn or cold-rolled shafting is much stronger per unit of cross-section than before the cold-working, and wire may be made whose ultimate strength is increased several times by the strains set up in the drawing operation. Wire-drawing strains give to some varieties of spring wire the greater part of their springiness. The increased strength of iron and steel wire due to the strains of cold-working is made useful in many ways. In the wire cables of suspension-bridges it is relied upon and figured in as part of the tensile strength of the wire.

The modifications and removal of strains due to cold-working by heating for long or short periods of time, one or more times, to temperatures below redness requires investigation. By these temperatures is meant those all the way down to atmospheric, and especially those from 212° to 408° F., the latter being the temperature at which a faint straw colour is given to steel of a certain composition. Removal of dangerous strains by subjection to heat not great enough to discolour the surface of the metal would be a good thing in many ways, if feasible. A cold-worked piece of shafting, which will break off in the lathe when the outer skin is removed, might perhaps be practically cured by such heating between the rolling- or drawing-operations. In the specifications for wire for a suspension-bridge, the wire as drawn must have a tensile strength of 215,000 lb. per square inch, and after galvanising must have a tensile strength of 200,000 lb. per square inch. This decrease of 15,000 lb. per square inch is the loss of strength due to removal of strains by heating the wire for a brief period to the galvanising temperature, or, say, to 800° F. If the heating even at that temperature were long continued, a much larger loss of tensile strength would no doubt result.

It is held to be a fact that old iron and steel articles, years old, never have excessive strain and never fail through spontaneous rupture. It may, of course, be argued that they do not fail that way when old because if they contained enough strain to break spontaneously, they would have so broken when comparatively new; or, further, that if dangerously strained the fatigue of the metal would, in comparatively short time, allow it to break without any diminution of the strain. These arguments may be reasonable, but many believe, nevertheless, that there is a reduction of strain in iron and steel by the seasoning effect of time. Old cast-iron cannon which had given the normal amount of service were said to have had their strength restored by years of rest. The strains, in such cannon were, it is true, the result of service-stresses, but such strains in this case are analogous to those produced by cold-working, and especially as far as they are affected by annealing by time. In the case of an article of hardened steel, seasoning or annealing by time is held to relieve strains with the result that the piece is freed from danger of spontaneous fracture or change of shape after being finished, while if unhardened its strength and ductility are increased by such seasoning. In cold-worked steel the strength will probably decrease in time, as will the elastic limit, while the ductility will increase.

The question of seasoning by time brings up the very interesting one of annealing iron and steel at low temperatures, that is, in the first phase, at not higher than 212° F.; in the second phase between 212° and the lowest temperature at which steel will be given the faintest straw colour, about 408°; and in the third at temperatures between this and red heat. The temperatures giving steel the tempering colours, straw, yellow, blue, &c., vary for different grades of steel, and therefore cannot be stated exactly for steels as a whole. There is much to be learned in these fields, and the second of the three mentioned seems especially to hold out hope of practical benefit to mankind from application of its laws.

That strains in hardened steel are of a quite different nature from those in cold-worked steel, may be shown by the attraction of a magnet. A piece of hardened steel with and without intense strains acts very differently from a piece of wire-drawn steel with and without strains when its attraction for or by a magnet is measured.

No solution of the problems presented by the phenomena of the hardening and tempering of steel, however, will be complete which does not deal with the strains arising, their causes, results, and proper treatment. Neither is the mathematical treatment of the matter of strains here considered, requiring as it does examination of intricate problems involving variations in temperature, coefficient of expansion, moduli of elasticity in tension and compression and at different temperatures, physical properties, varying kinds and intensity of strain in the different parts of the piece, and perhaps other important factors.

The author hopes that other investigators may select these questions for research, as without such investigations failures will always occur, notwithstanding that a large factor of safety may be believed to have been secured.

EFFECT OF LOW TEMPERATURE ON THE RECOVERY OF STEEL FROM OVERSTRAIN.

BY E. J. McCAUSTLAND (ITHACA, NEW YORK).

[*Abstract.*]

THE behaviour of steel after overstrain and at moderate temperatures is fairly well known. It has been made the subject of much investigation, and our knowledge is clear and definite on many points.

The behaviour of overstrained steel at temperatures at or below 32° F. is not so well known. Tests made by Professor E. G. Coker, at McGill University,* show that steel, overstrained and subjected to cold, will remain in a state of overstrain for an indefinite period.

The effect of time and temperature on the recovery of steel from overstrain was, in 1902–3, made the subject of some investigation in the laboratories of the College of Civil Engineering of Cornell University. A general plan was outlined in connection with the regular courses of instruction in testing of materials; but the press of routine work and the demands of the schedules on the time of the students were so great as to presage long delay in the completion of the work. Not much had been accomplished up to 1904–5, when Messrs. E. C. Johnson and W. F. Pond chose this subject for a thesis investigation under the author's direction. Altogether, about 120 separate tests were made.

The outline of the experiments was as follows:—

SCHEME OF EXPERIMENTS.

I. *Tests after Moderate Temperatures.*—Investigate the effect of time on the recovery of steel from overstrain, the specimen being subjected to moderate temperatures only, *i.e.* temperatures ranging from 60° to 70° F.

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* *Physical Review*, vol. xv. No. 2, 1902.

II. *Tests after High Temperatures.*—Investigate the accelerating effect of high temperature on the time of recovery of steel from overstrain. (The high temperature referred to throughout this paper is that of saturated steam.)

III. *Tests after Low Temperatures.*—Investigate the retarding effect of low temperatures, *i.e.* temperatures below 32° F., on the time of recovery of steel from overstrain.

IV. *Tests after Low-High and after Low-Moderate Temperatures.*—Investigate the effect of high and also of moderate temperatures on the recovery of overstrained steel which has been subjected for a considerable period to a low temperature.

MATERIALS USED IN THESE TESTS.

Two kinds of steel were used in making these tests :—

1. The grade known as "extra soft," the specimen being 2 inches wide, and cut from a ⅝-inch plate, thus giving a sectional area of 1·25 square inches. The pieces were sheared wider than 2 inches, and then milled down to gauge.

2. A mild steel, received in the form of ⅝-inch round rods, which were not turned down at all, but were tested with the "skin" on. The area of these rods was taken as 0·312 square inch.

METHODS OF TESTING.

The general method followed in making these tests was the same for all the pieces tested. Measurements were taken to determine elongations on a gauge-length of 8 inches, the extensometer apparatus being of the double micrometer screw type, with electric contact, and reading directly to 0·001 inch, and by estimation to 0·0001 inch. To determine the stress-deformation relations, loads were applied, increasing by equal increments, and the micrometers were read at each loading, to determine the elongations. The load was occasionally reduced to zero, and the micrometers read in order to determine the amount, if any, of the permanent elongation of the piece.

Cyclical Loadings.—When it was found that the elastic limit had been slightly exceeded, and a permanent stretch of from 0·03 to 0·06 inch in the 8-inch gauge length had taken place, the load was entirely removed; the micrometers were reset to 8-inch gauge; and a second test was made with loads rising by equal increments up to a point slightly beyond the original elastic limit, and then returning by equal decrements to zero.

TEMPERATURE CONDITIONS.

The "moderate" temperatures referred to throughout are those usually prevailing in the room adjoining the laboratory, which varied from 60° to 70° F. The "high" temperatures refer to those cases in which the specimen was subjected for 45 minutes to a steam bath in a copper boiler. The "low" temperatures were obtained by placing the specimens in one of the refrigerating-rooms near the laboratory.

DISCUSSION OF TESTS BY GROUPS.

Moderate Temperatures.—About 40 tests were made on eight different specimens kept at moderate temperatures, and of these specimens, two of each kind of steel were chosen as representing the typical behaviour for these conditions.

The curves for mild steel agree closely, notwithstanding the fact that the time of recovery is somewhat widely different. A number of cyclical loadings were run on both these specimens. A comparison of the average times of recovery for the two kinds of steel shows that the mild steel recovers much more slowly than does the soft steel.

High Temperatures.—In this group, seven specimens were tested, a large number of observations being taken which are not here included.

Only two specimens of mild steel were tested for the effect of high temperature. It is very probable that the difference found in the time of recovery of these two specimens was, in large measure, due to the difference in the maximum load attained in the respective cycles, which, although it amounted to only 700 lbs. per square inch, would have a comparatively large effect in the region of the elastic limit.

Low Temperatures.—In this group also, seven separate pieces were tested. The stress-deformation relations in a piece of soft steel were determined in the usual manner, and the test was followed at once by the cyclical loading. The piece was at once removed from the machine, packed in ice, and placed in cold storage, from which it was removed for a cyclical loading-test at intervals covering a period of 2112 hours. After it had been at a freezing temperature for this number of hours, and, in addition, had rested at a moderate temperature for a period of 24 hours, there was no indication whatever of recovery. On the contrary, there seemed to be a gradual breaking down of the material. In all, 13 cycles were run on this piece.

Another specimen, a piece of soft steel, was tested in much the same manner, but was left for a much longer period under the influence of low temperature. The piece was originally tested in April, and remained in cold storage all summer, the final tests being made in November.

The time of recovery at moderate temperature of these specimens of extra soft steel is about double the time required in the cases of those pieces which had not been subjected to the influence of low temperature for any time.

SUMMARY OF TESTS AND CONCLUSIONS.

Table I. gives a summary of the tests, so that the time of recovery from overstrain under different temperature conditions, and for the two kinds of steel, may be appreciated at a glance.

TABLE I.—*Summary of Tests.*

No.	Kind.	Elastic Limit. Lbs. per Sq. In.	Stretch in 8 Inches.	Hours of Freezing. Temp.	Time of Recovery.		Remarks.
					Moderate Temp.	After Steam Bath.	
			Inches.				
1	Soft	27,500	0·0339	None	68	...	
2	Soft	28,000	0·0366	None	69	...	
3	Mild	32,000	0·0632	None	434	...	Increased time of recovery due to greater stretch
4	Mild	32,000	0·0372	None	359	...	
5	Soft	28,000	0·0517	None	...	25	
6	Soft	28,000	0·0512	None	...	26	
7	Mild	30,000	0·0129	None	...	24	
8	Mild	30,000	0·0147	None	...	119	Increased time of recovery possibly due to higher cyclical loading
9	Soft	27,000	0·0244	2,112	142	...	
10	Soft	27,500	0·0462	4,727	120	...	
11	Mild	30,000	0·0206	2,707	...	93	
12	Soft	28,500	0·0468	2,111	...	24	

An examination of Table I. shows clearly that all the tests of which specimens Nos. 1 to 8 are types exhibit results quite in harmony with those obtained by other experimenters along these lines. I am not aware of any tests which take into account the variation in the carbon-content of the steel, as affecting the time of rcoovery from overstrain; but it appears from these experiments that recovery is more gradual as the carbon increases. Specimens Nos. 5 and 6, of soft steel, show in a marked degree the accelerating effect of high temperature on the time of recovery. Since only two tests, Specimens Nos. 7 and 8, were made on the mild steel, and since these show widely varying results as to time of recovery after the application of heat, it can be concluded only that high temperatures hasten recovery to a degree which remains uncertain without further tests. As to these particular pieces, it may be possible that the difference in time of recovery is due, to some extent at least, to the higher cyclical loading to which Specimen No. 8 was subjected.

With regard to the question upon which it was the object of these experiments to obtain light, the evidence appears conclusive that the effect of continued low temperature on a piece of steel which has been stretched slightly beyond the elastic limit, is to arrest completely the recovery of its elastic properties. That is, if the permanent elongation has not exceeded, say, 1 per cent., no recovery of elastic properties will take place while the specimen is kept at a temperature at or below 32° F. Maxwell,* in his article on "Constitution of Bodies," says: "We know that several substances, such as gutta-percha, india-rubber, &c., may be permanently stretched when cold, and yet, when afterwards heated to a certain temperature, they recover their original form." This appears to be true in the case of steel, provided the deformation has not been excessive. No difference can be appreciated in this regard between the two kinds of steel included in these tests. Nor does it appear that the possibility of a final recovery is at all interfered with by a long period of rest at a temperature below the 32° F. In the soft steel specimens Nos. 9 and 10, it is true that the time required for recovery after the specimen was removed from the influence of the low temperature was considerably greater than in the case of those specimens, Nos. 1 and 2, which had never been subjected to anything but moderate temperatures. The author is of opinion, however, that this difference in the time of recovery was due, not to previous temperature conditions, but rather to the differences in the percentages of elongation in the various specimens. As a final remark, having for its purpose the suggestion of an explanation of the foregoing phenomena, the closing paragraph of Professor Maxwell's article, already cited, is pertinent:—

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* *Encyclopædia Britannica.*

"This view of the constitution of a solid, as consisting of groups of molecules, some of which are in different circumstances from others, also helps to explain the state of the solid after a permanent deformation has been given to it. In this case some of the less stable groups have broken up and assumed new configurations, but it is quite possible that others, more stable, may still retain their original configurations, so that the form of the body is determined by the equilibrium between these two sets of groups; but if, on account of rise of temperature, increase of moisture, violent vibration, or any other cause, the breaking up of the less stable groups is facilitated, the most stable groups may again assert their sway and tend to restore the body to the shape it had before its deformation."

The paper is accompanied by eighteen detailed tables of the results of the tests, and twelve diagrams in which these results are plotted as curves.

A NEW COLORIMETER FOR THE DETERMINATION OF CARBON IN STEEL.

BY CHARLES H. WHITE (CAMBRIDGE, MASS.).

[*Abstract.*]

EACH of the current methods of colorimetry has excellent points to recommend it; but, as is well known to experimenters, there are serious objections to all of them, as they have hitherto been applied in practice.

The colorimeter described was designed for rapid and accurate application, and has proved itself free from many of the objections belonging to those previously devised. In this method, equal quantities of the standard and of the unknown steel are dissolved in equal volumes of the solvent, diluted to given volume, and varying thicknesses of the solutions com-

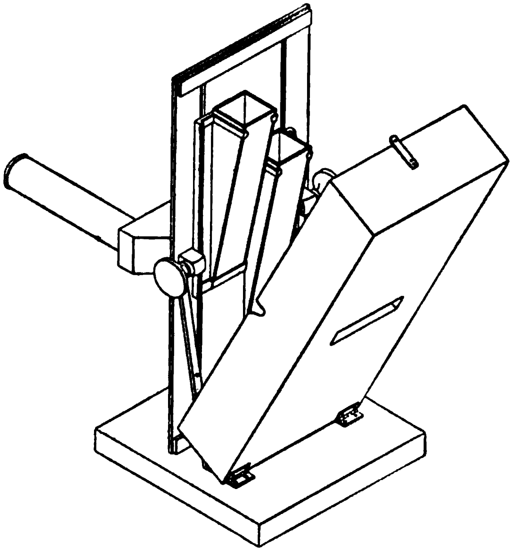

FIG. 1.

pared until the colours agree. The ratio of the thickness of the two solutions compared is then inversely proportional to the percentages of carbon present. In using this apparatus, the two steels, the standard and the unknown, are dissolved in the usual manner in large test-tubes, diluted to equal volumes, indicated by a mark on the tubes, and the solutions are compared in hollow glass wedges. The wedges must be of equal angle, and it is convenient to have them as nearly as possible of equal size. The large end is left open for the introduction of the solutions, and they are mounted side by side in a vertical position for comparison. Each wedge may be raised or lowered by means of a thumb-screw, carrying a pinion which engages with a rack holding the wedge. (See Fig. 1.) The wedges are encased in a box, which is provided with a narrow horizontal aperture in both the front and back, admitting of the direct passage of the light through the wedges of this zone only. In front of the aperture, or slit, are three mirrors, shown in Fig. 2, arranged in such a manner as to render the comparison of the colours easy and exact. The band of light, as observed in mirror *C*, through the tube *T*, is composed of three nearly equal parts. The central portion comes from the wedge *S*, and is reflected from the mirror *A*, through that portion of mirror *B* from which the

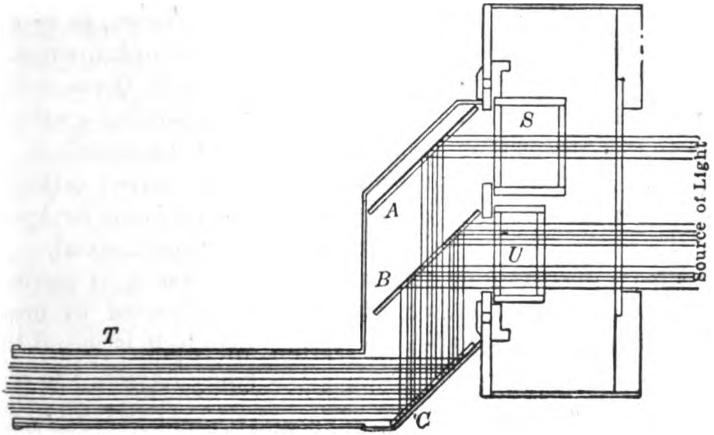

FIG. 2.

silver has been removed. The outer portions of the coloured band of light come from the wedge *U*, and are reflected from the silvered portions of mirror *B*. The racks which carry the wedges carry also graduated scales on the front of the instrument, which show, in every position, the distance from the sharp edge of the wedge to the slit where the comparison is being made. Uniform illumination is secured by admitting the light to the solutions through a piece or pane of ground glass, shown in section in Fig. 2.

In operating with this instrument, if the wedges are so adjusted that the colours are of equal intensity, and if their thickness at the slit—the point of comparison—is determined, or the ratio of one to the other is known, it is easy to calculate the percentage of carbon in the unknown steel. Since a longitudinal vertical section of one of these wedges is triangular and equal in all respects to a similar section of the other wedge, we are not restricted to the measure of the thickness of the solutions to determine the desired ratio, but the length of each from its sharp edge to the point compared may be read off on its graduated scale and used instead.

Suppose, for example, the standard steel has 0·30 per cent. of carbon, and after the wedges have been adjusted, by means of the thumb-screws until the colours match, it is found that the scale on the side of the standard reads 72 and the scale of the other wedge reads 60; then the proportion: $60 : 72 = 0{\cdot}30 : x$ shows that the percentage of carbon in the steel under examination is 0·36. But the solutions in the wedges may be as easily compared at the graduations 30 and 36 as at 60 and 72; and if the scale on the side of the undetermined steel is set at 30 and the other wedge, carrying the standard, is adjusted until the colours are equal, then its scale must read 36, which gives at once the desired figure.

It is obvious that with this instrument the standard can be varied at will from the highest to the lowest in carbon, and the difficulties attending attempts at permanent standards avoided. Haphazard diluting is obviated, while the wedges are as easily emptied and filled as test tubes. The chief advantages, however, derived from the use of this instrument are the speed and accuracy with which the colours are matched, and the fact that the percentage of carbon is read off directly.

The accuracy of the instrument increases as the angle of the wedge diminishes. Very thin sections of coloured solutions are not easily matched, and long wedges are unwieldy and in many ways objectionable. It is not necessary, however, to use the whole length of the wedge; for the standard and the unknown steel cannot differ greatly in the amount of carbon contained, and therefore in the colours produced when in solution. The wedges, then, may be designed to have any suitable angle, and only so much of the large end need be used as will afford the range desired. In other words, the wedges are cut off, the lower end of the upper portion sealed, and the lower part discarded. The scales, however, must be graduated to accord with wedges of the full length. Wedges of this type are useful for the most exact colorimetric work, but with the ordinary size comparisons are quickly made and read with accuracy to the second decimal place, which is as high a degree of accuracy as other parts of the colour-method for carbon in steel can be relied upon to give.

DEPUTATION TO THE KING.

On Friday, July 27, 1906, His Majesty the King received, at Buckingham Palace, a deputation from the Iron and Steel Institute and the American Institute of Mining Engineers. The Earl Granville, Lord-in-Waiting; Lord Farquhar, G.C.V.O., Master of the Household; Colonel Lord Edward William Pelham Clinton, G.C.V.O., K.C.B.; Colonel Sir Arthur Davidson, C.V.O., K.C.B.; and the Hon. John Hubert Ward, M.V.O., Groom and Equerries in Waiting; and Lieut.-Colonel Charles Frederick, C.V.O., Deputy Master of the Household, were in attendance.

Mr. R. A. Hadfield, President of the Iron and Steel Institute, had the honour of being presented to His Majesty by the Lord-in-Waiting, and afterwards introduced the deputation, consisting of the following representatives of the Iron and Steel Institute: The Rt. Hon. Sir James Kitson, Bart., M.P., D.Sc. (Past-President); the Rt. Hon. Victor Cavendish (Vice-President), Sir Hugh Bell, Bart. (Member of Council and President-Elect), and Mr. Bennett H. Brough (Secretary).

The representatives of the American Institute of Mining Engineers presented were: Captain R. W. Hunt (President), Dr. R. W. Raymond (Secretary and Past-President), Mr. C. Kirchhoff (Past-President), Mr. T. Dwight (Member of Council), Mr. W. Wood (Member of Council), Mr. B. F. Fackenthal (Past-Officer), Mr. J. Hartshorne (Past-Officer), and Mr. Oberlin Smith (Past-Officer).

The President (Mr. R. A. Hadfield) then offered the Bessemer Gold Medal of the Iron and Steel Institute to His Majesty, and an illuminated address, saying:—

"I beg your Majesty, on behalf of the Iron and Steel Institute, to receive the Bessemer Gold Medal, the acceptance of which, I can assure your Majesty, will be esteemed as a great mark of condescension and the highest honour which can be conferred on that body of your Majesty's loyal subjects."

The King was graciously pleased to accept the Medal, and replied to the address. His Majesty inquired regarding the work of the joint meeting of the two Institutes, and expressed the hope that the American visitors would enjoy their stay in Great Britain.

The deputation then withdrew.

The illuminated address was worded as follows :—

TO THE KING'S MOST EXCELLENT MAJESTY.

May it please Your Majesty,—

We, the President, Council, and Members of the Iron and Steel Institute, beg leave to approach your Majesty with sentiments of dutiful loyalty, and to request your Majesty to honour the Institute by accepting the Bessemer Gold Medal, instituted in 1874 for award for conspicuous eminence in the iron and steel industries, as a slight indication of our appreciation of the warm interest your Majesty has shown, as Honorary Member of the Iron and Steel Institute, and, since your Majesty's accession to the Throne, as Patron, in those industries upon which the prosperity of your Majesty's Dominions so largely depends.

Sealed with the Seal of the Iron and Steel Institute, this twenty-fourth day of July, 1906, in the presence of—

L.S.

R. A. HADFIELD, *President.*
BENNETT H. BROUGH, *Secretary.*

THE ANNUAL DINNER.

THE annual dinner of the Iron and Steel Institute, to which the members of the American Institute of Mining Engineers were invited, was held in Guildhall, on the evening of Friday, July 27, by the courtesy of the Court of Common Council of the City of London. The President, Mr. R. A. Hadfield, presided, and was supported by Sir Hugh Bell, Bart. (President-Elect), the Right Hon. Sir James Kitson, Bart, M.P., Mr. E. Windsor Richards, Mr. E. P. Martin, and Mr. W. Whitwell (Past-Presidents), and by the Vice-Presidents and Members of Council. About 100 members of the American Institute of Mining Engineers were present, including Captain Robert W. Hunt (President), Mr. James Gayley, Mr. Charles Kirchhoff, Mr. E. G. Spilsbury (Past-Presidents), Mr. Joseph Hartshorne, Mr. Oberlin Smith, Mr. Theodore Dwight, Mr. Walter Wood, Mr. Julian Kennedy, Mr. Edgar S. Cook (Members of Council), and Dr. R. W. Raymond (Secretary), whilst among the noblemen and gentlemen present to meet the American visitors were the Right Hon. the Lord Mayor (Alderman Sir W. Vaughan Morgan), and the Sheriffs of the City of London (Sir T. G. Bowater and Sir H. G. Smallman), Count Herman Wrangel (Swedish Minister), the Earl of Bessborough, Lord Stanley of Alderley, Lord St. Oswald, Lord Kelvin, G.C.V.O., Lord Allerton, Lord Glantawe of Swansea, the Right Hon. R. B. Haldane, M.P. (Secretary of State for War), Sir Theodore Fry, Bart., Admiral Sir A. L. Douglas, K.C.B., G.C.V.O., Sir Norman Lockyer, K.C.B., General Sir J. Wolfe Murray, K.C.B. (Master-General of the Ordnance), Sir William H. White, K.C.B., Colonel Sir Howard Vincent, K.C.M.G., M.P., Sir James Dewar, Sir Joseph Leigh, Sir Christopher Furness, M.P., Sir George Gibb, Sir Alexander Kennedy, LL.D., General D. O'Callaghan, C.V.O. (President of the Ordnance Committee), Rear-Admiral A. J. Montgomerie, C.B., C.M.G., General F. T. Lloyd, C.B., R.A., Mr. Maurice Fitzmaurice, C.M.G., Captain H. B. Jackson (Controller of the Navy), Mr. Herbert L. Samuel, M.P. (Under Secretary of State for Home Affairs), the Venerable Archdeacon Sinclair, the Master Cutler of Sheffield (Mr. Sydney J. Robinson), Admiral Coerper (Naval Attaché to the German Embassy), Captain Gibbons (Naval Attaché to the United States Embassy), Colonel Minchin, and Mr. Septimus Vaughan Morgan.

The company, which numbered 600, was received in the Corporation Art Gallery by the President, and on the guests assembling for dinner in the Guildhall, grace was said by the Venerable W. M. Sinclair, D.D., Archdeacon of London and Canon of St. Paul's.

The President, in giving the toast of "His Majesty the King, Patron of the Iron and Steel Institute," said that many kings had been present in that historic hall, but none had been more popular in the hearts of the people than His Majesty King Edward.

The President next proposed the health of Her Majesty Queen Alexandra, their Royal Highnesses the Prince and Princess of Wales, and the other Members of the Royal Family.

The President then said he had a very special toast to submit to them, and that was one which he knew would be very popular with every Englishman present, and also with their American guests; he referred to the toast of "The President of the United States of America." One of their great statesmen had recently put forward the view, with which he was sure that they would all agree, that Mr. Roosevelt had done more for the promotion of peace than any other statesman of the present day. He was a man with a wide range of knowledge, of whom they might well be proud. In giving the toast, every Englishman would join with their American friends in wishing health and long life to President Roosevelt.

The President next gave "The Lord Mayor and Corporation of London." By the kindness of the Lord Mayor and of the City Lands Committee they were privileged to meet in that historic hall, dating back to the thirteenth century, a privilege seldom granted since the time of Dick Whittington. They were exceedingly obliged to the Lands Committee, and to the Lord Mayor, who had kindly consented to act as chairman of the reception committee, and who had given a great deal of time and attention to the subject, and when they were informed that the Lord Mayor, who was a business man, had to go through over twelve hundred functions in his year of office, they would appreciate his kindness on this occasion.

The Right Hon. the Lord Mayor, in acknowledging the toast, said he would express in a few words the pleasure that the Corporation had had in placing Guildhall at the disposal of such good company. He felt that they could not make a much better use of Guildhall than they were doing that evening, in bringing together some of the most important citizens of the United States and the little kingdom of Great Britain.

Lord **ALLERTON** next proposed "The Imperial Forces." He said in an assembly such as that there was some touch of sympathy between the Imperial Forces and the Iron and Steel Institute. He imagined that the Imperial Forces were largely dependent for their efficiency upon the Iron and Steel Institute, and he could imagine that although they knew that the Institute was not dependent upon anybody, still at the same time it had a kindly feeling towards the Imperial Forces. The toast he had to propose included the Navy, which stood at the head of the Imperial Forces. He believed that the British Navy would give a good account of itself when called upon to do it. They trusted greatly to their Navy; and at the same time he believed it was necessary to have a strong and efficient army, for they could never tell when the moment would come when they would be called upon to strike, and to strike effectively.

Admiral Sir **ARCHIBALD DOUGLAS**, K.C.B., G.C.V.O. (Commander-in-Chief at Portsmouth), replied on behalf of the Navy, which he described as a steel-embodied Navy. Whatever their personnel and their patriotism might be, without good iron and steel they should be as one who beateth the air. Fifty years ago, when he first joined the Navy, they had not one steel ship. Now things were changed. Force and pluck were not less required at the present time, but these qualities had to be tempered with a great deal more knowledge. The difficulty now was to keep pace with development, and to fill with life and nerve power those powerful ships with which the makers of steel were so constantly providing them.

The Right Hon. R. B. **HALDANE**, M.P. (Secretary of State for War), in replying for the Military Forces, observed that a War Minister was generally applauded so long as he kept to talking, but so soon as he proceeded to do anything the applause became somewhat mixed. The Navy was in a happier position. His friend Admiral Douglas expressed great confidence that, if there was to be retrenchment, it should be retrenchment of the Army. Well, he would take the country into his confidence and tell them what in Pall Mall they dreaded. They dreaded lest the public should take the Navy at its word and set to work to retrench the Army. He would fain see the time when the nations with one accord should relieve themselves and each other of the burden which bore them down, at least in some degree. But he could not forget that so long as things remained as they were at the present moment their responsibility was a heavy one. Thousands of miles from here, wherever the dominions of the Crown extended, they had to maintain those forces, not for aggression but for defence and security. They would set aside what was useless, and insist upon everything being organised for war, so that they might meet any difficulty that might confront them. Through blood and tears the great inheritance of the nation had been won, and it was theirs to strive by every means in their power to hand down that inheritance undimmed and unstained to those who would come after them.

Sir HUGH BELL, Bart. (President-elect), next proposed "The Houses of Parliament." He wished to remind those present that they were in a room well described by the President as an historic chamber whose title gave a key to the purposes for which its founders destined it; it was the Guildhall. Now, the Guildhall was essentially the chamber used for the purpose of commerce, and it seemed no unfitting thing that a great industrial assembly, the Iron and Steel Institute, should have been permitted to hold its banquet in the Guildhall of the City of London. He would also remind them that out of the municipal life of this country in large measure sprang parliamentary life, and that, therefore, he might not unreasonably connect the Guildhall with Parliament, and ask them to pass from the subject of Guildhall to that of his toast. He had hoped to have been permitted to connect with that toast the name of a distinguished member of the Institute—who had, indeed, a hereditary connection with it; he meant the Duke of Devonshire, the son of their first President. Circumstances, unfortunately, prevented him having that pleasure, but he had still to connect the name of one who had a family connection, if not a hereditary connection, with the Iron and Steel Institute, Lord Stanley of Alderley. Reverting to the toast of the House of Commons, he wished to point out that in praising it they were praising themselves. On the other hand, if they blamed it they were blaming their own creation, a creature which they brought into existence but a few months ago. Therefore he would abstain from offering any distinctive commendation, or the reverse, of the House of Commons.

Lord STANLEY OF ALDERLEY said he was called upon to return thanks for the Hereditary Chamber of the Legislature. Probably to an assembly of business men, and especially to that large section present who came from across the Atlantic, the idea of hereditary transmission of functions might seem ridiculous and superannuated, yet he thought that the Iron and Steel Institute itself had shown that they were not free from that ancient taint of hereditary English habit, for they had made the proposer of the toast the President of the Iron and Steel Institute for the coming year, and they all knew how great a part Sir Hugh's father had played in the founding of that Institute. It was a bold thing in such an assembly to speak on behalf of a hereditary institution. But he could not help feeling that there was something in the *genius loci* of the City which might excuse him in speaking on behalf of the House of Lords, because the City of London and the House of Lords were two great historic institutions which had come down from a remote past, and they had both refused to allow the sacrilegious hand of reform to touch them.

Mr. **Herbert Samuel**, M.P. (Under-Secretary of State for Home Affairs), responded for the House of Commons. He said this was the toast to which it was hoped the Prime Minister would have responded, but he had to express on his behalf his great regret that other claims had kept him away. The Prime Minister had, however, asked him to convey a very cordial welcome to the American guests who were honouring this country with a visit. These international visits between trades, professions, municipalities, parliaments, and sovereigns were of infinite use in spreading those principles of peace and goodwill to which in this country His Majesty the King, the Ministry, and the present Parliament were at one in desiring to promote. A distinguished statesman in a speech at the Guildhall told the nation that it should learn to think imperially. That was advice with which he for one had no quarrel; but he thought perhaps that while they were thinking imperially they should now and then learn to think internationally as well, and it was visits such as that which helped them to do so. Nowadays the alliances between nations were for the maintenance of peace. Such an alliance had long subsisted between the great Anglo-Saxon nations, an alliance expressed in no treaty, but existing in that which was far stronger than a treaty—in the determined will of two great democracies. They all hoped that the visit of the American Mining Engineers to that Institute would help to bind the two nations together with bonds of iron and hoops of steel.

The Right Hon. Sir **James Kitson**, Bart., M.P. (Past-President), proposed "Our American Guests." He said he owed the distinction of proposing this toast to the accident that he was President of the Iron and

Steel Institute on its memorable visit to the United States in the year 1890; and he was fortunate in being able to repeat to their guests some expressions of gratitude which had been expressed in the past, and were again expressed on that occasion. The visit of the Iron and Steel Institute in 1890 recorded a distinct epoch in the relation of the iron trades of Great Britain and the United States, for it was in the year 1890 that the United States manufacturers first exceeded, in their production, the output of iron in the United Kingdom. He would remind them that in 1890 the output of pig iron in Great Britain was 8½ million tons, and in the United States 9½ million tons. They still continued to maintain their position, but the Americans, owing to the great expanse of their territory and extension of their railway system, had made extraordinary developments; and in the past year, while their own production had been 9½ million tons, the American production had been 23 million tons. What was more remarkable was that out of that 23 million tons of pig iron, 20 million tons were converted into steel. This steel was being used for those magnificent picturesque buildings which they saw in the United States. It was being used in the extension of their railways, which now amounted to ten times the mileage of those in the United Kingdom. In proposing this toast, and in returning to the Americans thanks for their kindness on the two memorable visits the Institute had made to America, he would say those were kindnesses and friendships which would never be forgotten. They had visited Pittsburg, where the Americans had done many wonderful things. They had set the river Monongahela on fire by great fountains which were fired and which blazed in their honour. At Chicago they had conferred upon them the freedom of the city, and they were the better for it. At Chicago they were also given a great banquet, and they had been no worse for it. At Washington they had been received on both occasions by the President of the United States—by President Harrison in 1890, and in 1904 by President Roosevelt. His Majesty the King had returned the compliment which was paid to the nation by that day receiving, at Buckingham Palace, a deputation of the American iron trade. He ventured to say that the personal friendships of the great chiefs of a great industry would do far more to unite the Anglo-Saxon race in promoting the prosperity and the extension of manufactures in the world, and therefore the prosperity of those who depended upon it for employment than anything else.

Captain ROBERT W. HUNT (President of the American Institute of

Mining Engineers), in replying to the toast, said he wished that the duty, the pleasure of responding to the sentiment which Sir James had so eloquently and graciously given, could have fallen to one better fitted than himself. He could, however, assure them that, while such a one might have replied in words more eloquent, he would not have been inspired by any warmer appreciation of the great kindness, the most generous hospitality, which he and his colleagues had been and were receiving at the hands of the Iron and Steel Institute. The members of the American Institute of Mining Engineers appreciated most sincerely the compliment which was extended to them by having that banquet in that historic hall. The American Institute of Mining Engineers, like the Iron and Steel Institute, was a cosmopolitan organisation, having members of many nationalities, residing in far-distant parts of the world. Nevertheless its language was English, its organisation was English, and it might be said to think in English. It had always seemed perfectly appropriate for the Iron and Steel Institute to hold meetings in New York; and the American Institute of Mining Engineers had been feeling equally at home while holding their sessions in London. Honoured as they felt by the distinction of being guests in that historic hall, they at the same time felt that, to a certain extent, they had come home to their own. The United States had drawn and was drawing on all the nations of the earth for its population; they were a nation to whom the traditions of England belonged as a heritage. In his own city, the electric light and power were supplied by a Corporation which was directed by a man Oxford born. It had the second largest banking institution in the Western Hemisphere. The President and its Vice-President were Scotsmen. One of their local steel companies became an important factor in the first consolidation, the success of which, no doubt, had much to do with the later great United States steel organisation. That local company was brought to the successful financial position which rendered it an important element in the movement by a gentleman, an officer in the British Navy, and a member of the Iron and Steel Institute, who had later returned to his native land, there to enjoy not only the fruits of his American success, but also inherited honours. It had been the speaker's good fortune to have him for a friend while in America, and he regretted he was not there to-night. He referred to Lord Leith of Fyvie. Great Britain sent another son to America who was destined to play an important part in its commercial affairs—in fact, to expand the sphere of his influence until its effects were not confined to any country. He taught them in America to think in millions—a man who, while a loyal citizen of his adopted country, had never ceased to love his native land—in fact, a man so interwoven with the affairs of both hemispheres that he belonged to both. He was a member of both Institutes, and a Past-President of one of them. His deeds spoke for themselves—Dr. Andrew Carnegie. Last year the American Institute of Mining Engineers held a meeting at Victoria, Vancouver. They had seen much of the North-West, part of the time as guests of the territorial Governments. What they saw of it only served to impress them with the feeling of how small a portion it was of the great whole. Canada's mineral wealth and agricultural possibilities destined her to a brilliant and powerful future. Thousands of sturdy farmers had been and were emigrating from the United States to that North-West, attracted by its wonderfully fertile plains, which had been made accessible by the country's great railway development. In the records of the American Institute of Mining Engineers there were already many illuminated pages, but hereafter the brightest of all would be the recording their London meeting. Let that record be ever so graphically written, it would fail to do justice to the event. The only truthful record of their kindness and hospitality must and would be engraved upon their hearts.

Dr. R. W. **Raymond** (Secretary of the American Institute of Mining Engineers) next proposed "The Iron and Steel Institute." He said that was the third occasion upon which he had been called upon to present that toast. He took the liberty of imagining that there was some particular ability which he possessed for appreciating the excellence and extolling the glory of the Iron and Steel Institute. In 1890 he presented that toast in New York, and again in 1904. On the first of these occasions he took the opportunity of celebrating the part which the American and English engineers had taken in the conquest of a continent, describing the way in which mining engineers going in the van of civilisation and of industries had awakened to life the resources of a new empire. He took the liberty then, although he was sixteen years younger than he was that day, to speak like an old man to his younger brothers, and to tell them that they would never live through an era as important as he and his contemporaries had experienced, because there would be no more such worlds to conquer. Well, he had been mistaken! When their American Institute went through British Columbia they had a chance of realising how their brothers of Canada had found another world to conquer beyond the limits of the world that Americans thought their own. He could only add his meed of praise to what Captain Hunt had already uttered concerning the wealth, the progress, and the glorious future of the Dominion of Canada. The United States had had matrimonial intentions upon Canada once upon a time, but, with that skill which the ladies always seem to possess, she saved the Americans from unnecessary embarrassment and humiliation by intimating that she would be a sister to them. Since that time they had gone considerably into matrimony in other directions. When he reflected upon Porto Rico, the Sandwich Islands, the Philippines, and Guam, he might almost say they had plunged into polygamy; but he would say this, that one such sister was worth a hundred of such wives. He was sure that his American brethren would join with him in the sentiment which he had had the honour to utter in the Dominion of Canada, that it is better to be one under two flags than two under one flag. He was not thinking of such small matters as politics and diplomacy, the battles which were only the punctuation points of history; he was thinking of deeper and more permanent things. After he made his speech in 1890 he went almost immediately to Egypt, and there he found through the kindness of Lord Cromer, and especially of Sir Scott Moncrieff, who placed every facility at his disposal for the examination of the question he wished to study—he found what English engineers were doing to redeem Egypt. Politically? No; better than that. Diplomatically? No. He did not know, nor care, about the diplomacy of the situation. His American brethren would know what he meant when he said that at the time he came into Egypt it was becoming "alkalied" by a bad system of irrigation, and an accompanying misrule which was fast making the land uninhabitable. What the English engineers did was to redeem Egypt for all mankind. He told his English friends that he did not know what international right they had to be there, but he prayed they might remain. He wished to make a plea for a much-abused class. A great English critic had described as "Philistines" a certain kind of people. Now there were two kinds of people in this world—the Philistines, who do things, and the others who sit on the fence and make remarks. Engineers belonged to the Philistines. They were of the men who made two blades of grass grow where one grew before, while others were disputing as to who had the legal title to the grass. And engineers might claim from posterity, if not from their contemporaries, the verdict of praise for their work in steadily, patiently, and laboriously improving the product of human labour, in conquering and replenishing the world. Questions of distribution they might perhaps leave to philanthropists and to statesmen, but engineers produced the thing that was to be distributed, and without the Philistines, the saints would not be. He recalled the fact that the American revolution of the eighteenth century was no conflict between England and America, but a struggle in both countries between liberty and tyranny, in which the best and greatest Englishmen were with America. He gave them in 1890 a welcome from Uncle Sam upon their visit to the United States. In view of what he had just said, he would ask to be permitted to supplement that greeting by a message from Brother Jonathan:—

Now don't tell me the British oak
Was *split* by any lightnin' stroke!
Bless your soft head, that wa'n't a *split*,
But jest a fork, that doubled it!
'For Freedom ain't no sapling slim,
A-feared to grow another limb:
Thar's two big branches to that tree,
An' one is *you*, an' one is *me*,
  Sez Jonathan, sez he!

Your bough's the biggest up to date;
But mine has struck a lively gait,
An', fust you know, she'll shove her way
Right alongside o' yourn, some day,
While through 'em both, from foot to cap,
Tingles an' climbs the same old sap!
No matter whar them branches be,
Thar ain't but one trunk to that tree!
  Sez Jonathan, sez he.

What's more, we're both a-branchin' yet
With every blessed chance we get,
An' every limb that we send out
Is welcome to grow stanch and stout.
The sky above, the sile below,
Give room an' food for all to grow,
An' limbs an' leaves that flutter free
Jest add more glory to the tree,
  Sez Jonathan, sez he!

Grow on, O stalwart oak an' tall!
Spread wide thy branches, great an' small,
While in their shelter nest the birds,
And in their shadow stand the herds!
Lift all thy heads to greet the sun
That crowns with splendour every one!
So men, till men shall cease to be,
May praise and bless the ancient tree,
  Sez Jonathan, *say we.*

In conclusion, he begged leave to propose the toast of "The Iron and Steel Institute," coupling with it the name of the President, Mr. Hadfield.

Mr. R. A. **Hadfield** (President of the Iron and Steel Institute), in reply, thanked Dr. Raymond for the most eloquent way in which he had proposed the health of the Institute. He could only say that it had given the greatest possible pleasure to see the American guests there in London. They were going to send them north, and possibly by the time they had been to Glasgow there would not be much left of them. They would try and show British hospitality in return for the magnificent hospitality shown to them on two occasions in America. On behalf of the Institute, at that late hour, he could only briefly thank Dr. Raymond, who voiced the views of their American friends, for the eloquent way in which he had proposed the toast.

VISITS AND EXCURSIONS AT THE JOINT MEETING OF THE IRON AND STEEL INSTITUTE AND THE AMERICAN INSTITUTE OF MINING ENGINEERS.

In connection with the Joint Meeting of Members of the Iron and Steel Institute and the American Institute of Mining Engineers, an influential General Reception Committee was formed in order to make the necessary arrangements. The constitution of this committee was as follows:—

GENERAL RECEPTION COMMITTEE.

EXECUTIVE COMMITTEE.

R. A. Hadfield (*President*), Chairman.

W. H. Bleckly (*Treasurer*).
The Rt. Hon. Sir James Kitson, Bart., D.Sc., M.P. (*Past-President*).
E. Windsor Richards (*Past-President*).
E. P. Martin (*Past-President*).
Andrew Carnegie, LL.D. (*Past-President*).
Sir Hugh Bell, Bart. (*President-Elect*).
Bennett H. Brough (*Secretary*).

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Aird, John, & Co., London.
Akrill, C., & Co., Ltd., West Bromwich.
Anderston Foundry Co., Ltd., Port Clarence, Middlesbrough.
Armstrong, Sir W. G., Whitworth & Co., Ltd., Newcastle-on-Tyne.
Associated Portland Cement Manufacturers (1900), Ltd., London.

Babcock & Wilcox, Ltd., London.
Baird, William, & Co., Ltd., Glasgow.
Baldwins Ltd., Stourport.
Barclay, Andrew, Sons & Co., Ltd., Kilmarnock.

Barrow Hematite Steel Co., Ltd., Barrow-in-Furness.
Bayliss, Jones & Bayliss, Ltd., Wolverhampton.
Beardshaw, J., & Son, Ltd., Sheffield.
Bell Brothers, Ltd., Middlesbrough.
Bolckow, Vaughan & Co., Ltd., Middlesbrough.
Booth, Joseph, & Bros., Ltd., Leeds.
Briton Ferry Works, Ltd., Briton Ferry.
Butlin, Thomas, & Co., Ltd., Wellingborough.
Butterley Co., Ltd., Alfreton.
Byrne, James, & Co., Middlesbrough.

CARGO FLEET IRON Co., Ltd., Middlesbrough.
Carnforth Hematite Iron Co., Ltd., Carnforth.
Cochrane & Co., Ltd., Middlesbrough.
Coltness Iron Co., Ltd., Glasgow.
Colville, David, & Sons, Ltd., Motherwell.
Consett Iron Co., Ltd., Consett.
Cooke, William, & Co., Ltd., Tinsley.
Craggs, R., & Sons, Ltd., Middlesbrough.

DARWEN & MOSTYN IRON Co., Ltd., Mostyn.
Dorman, Long & Co., Ltd., Middlesbrough.
Dunlop, J., & Co., Ltd., Glasgow.

EBBW VALE STEEL, IRON & COAL Co., Ltd., Ebbw Vale.
Engineer, The Proprietors of, London.
Engineering, The Proprietors of, London.
Etna Iron & Steel Co., Motherwell.

FARNLEY IRON Co., Ltd., Leeds.
Firth, Thomas, & Sons, Ltd., Sheffield.
Flather, W. T., Ltd., Sheffield.
Fraser & Chalmers, Ltd., Erith.
Frodingham Iron & Steel Co., Ltd., Doncaster.

GJERS, MILLS & Co., Ltd., Middlesbrough.
Glenboig Union Fire-Clay Co., Ltd., Glasgow.
Glengarnock Iron & Steel Co., Ltd., Glengarnock.
Guest, Keen & Nettlefolds, Ltd., Birmingham.

HADFIELD'S STEEL FOUNDRY Co., Ltd., Sheffield.
Hall, J. & E., Ltd., Dartford.
Hardy Patent Pick Co., Ltd., Sheffield.
Harkess, W., & Sons, Ltd., Middlesbrough.
Harrison & Co., Ltd., Lincoln.
Head, Wrightson, & Co., Ltd., Stockton-on-Tees.
Hill, John, & Co., Middlesbrough.
Hingley, N., & Sons, Ltd., Dudley.
Hopper, John I., Ltd., Thornaby-on-Tees.
Hull Forge Iron & Steel Co., Ltd., Hull.

Iron and Coal Trades Review, The Proprietors of, London.
Ironmonger, The Proprietors of, London.

JACKMAN, Joseph, & Co., Ltd., Sheffield.
Jessop & Appleby Bros., Ltd., Leicester and London.
Jessop, William, & Sons, Ltd., Sheffield.

KIRKSTALL FORGE Co., Leeds.

LANARKSHIRE STEEL Co., Ltd., Motherwell.
Lilleshall Co., Ltd., Shifnal.
Linthorpe-Dinsdale Smelting Co., Ltd., Middlesbrough.
Lloyd, F. H., & Co., Ltd., Wednesbury.

MACFADYEN, P., & Co., London.
MacLellan, P. & W., Ltd., Glasgow.
Mason, Adam, & Sons, Bolton.
Mining Institute of Scotland, Hamilton.
Moss Bay Hematite Iron & Steel Co., Ltd., Workington.
Müller, W. H., & Co., Rotterdam.

NAYLOR, BENZON & Co., Ltd., London.
Normanby Iron Works Co., Ltd, Middlesbrough.
North-Eastern Railway Company, York.
North-Eastern Steel Co., Ltd., Middlesbrough.
North of England Institute of Mining Engineers, Newcastle-on-Tyne.

OAKES, James, & Co., Alfreton.
Otis Steel Co., Ltd., London.

PARKGATE IRON & STEEL Co., Ltd., Rotherham.
Pearson & Knowles Coal & Iron Co., Ltd., Warrington.
Pease & Partners, Ltd., Darlington.
Pickerings, Ltd., Stockton-on-Tees.

RAINE & Co., Ltd., Newcastle-upon-Tyne.
Richardson, Duck & Co., Stockton-on-Tees.
Richardsons, Westgarth & Co., Ltd., Middlesbrough.
Richmond Iron & Steel Co., Stockton-on-Tees.
Ridley, T. D., & Sons, Middlesbrough.
Ritchie, J. & R., Ltd., Middlesbrough.

SAMUELSON, Sir B., & Co., Ltd., Middlesbrough.
Sankey, Joseph, & Son, Ltd., Bilston.
Scott, Walter, Ltd., Leeds.
Seaton Carew Iron Co., Ltd., Seaton Carew.
Seebohm & Dieckstahl, Ltd., Sheffield.

Shaw, W., & Co., Middlesbrough.
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Simpson, James, & Co., Ltd., London.
Skinningrove Iron Co., Ltd., Skinningrove.
Slag Reduction Co., Ltd., London.
Smith, Frederick, & Co., Ltd., Halifax and Manchester.
Somers, Walter, & Co., Ltd., Halesowen.
South Durham Steel & Iron Co., Ltd., Stockton-on-Tees.
Spencer, John, Ltd., Coatbridge.
Steel Company of Scotland, Ltd., Glasgow.
Steel, Peech & Tozer, Ltd., Sheffield.
Stein, John G., & Co., Ltd., Bonnybridge.
Summers, John, & Sons, Ltd., Stalybridge.
Swan Brothers, Middlesbrough.

TALBOT CONTINUOUS STEEL PROCESS, Ltd., Middlesbrough.
Teesside Bridge and Engineering Works, Ltd., Middlesbrough.
Thomas, R., & Co., Ltd., Llanelly.
Thornycroft, John I., & Co., Ltd., Chiswick.

UNITED STATES STEEL PRODUCTS EXPORT Co., London.

VICKERS, SONS & MAXIM, Ltd., Sheffield.

WARD, Thos. W., Ltd., Sheffield.
Warren, Beattie & Co., Ltd., Middlesbrough.
Watson, James, & Co., Middlesbrough.
Watson, W. J., & Co., Middlesbrough.
Waverley Iron & Steel Co., Ltd., Coatbridge.
West of Scotland Iron and Steel Institute, Glasgow.
Whitehead, L. D., & Co., Tredegar.
Whitwell, W., & Co., Ltd., Stockton-on-Tees.
Wigan Coal & Iron Co., Ltd., Wigan.
Williamson, R., & Son, Workington.
Wilsons, Pease & Co., Ltd., Middlesbrough.
Wood, John, & Sons, Ltd., Wigan.
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The Rt. Hon. Sir James Kitson, Bart., D.Sc., M.P. (*Past-President*).
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Brown, P. B., London.
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HARBORD, F. W., London.
Hartlieb, J. F., London.
Hatton, George, Brierley Hill.
Hay, Walter R., London.
Hayne, W. Crosier, London.
Head, Benjamin W., London.
Henderson, James, Frodingham.
Hewlett, Alfred, Wigan.
Hill, W., Newcastle, Staffs.
Hopkinson, R. A., Huddersfield.
Horsfield, Arthur, Horbury.
Horsfield, S., Consett.
Howell, S. Earnshaw, Sheffield.
Hoyle, J. Rossiter, Sheffield.
Hughes, *Colonel* Herbert, C.M.G., Sheffield.
Hunsiker, *Colonel* Millard, London.
Hunter, J., Queen's Ferry.
Hunter, W., Stirling.
Huntington, *Professor* A. K., London.

JACK, A. G. M., Sheffield.
Jeans, J. Stephen, London.
Jenkins, J. G., Glasgow.
Jenkins, Thomas, Perry Barr.
Jones, C. L., London.
Jordan, A. J., Sheffield.
Justice, P. M., London.

KEEN, Arthur (*Vice-President*).
Keen, W. B., London.
Kirkaldy, W. G., London.

LAMBERTON, Andrew (*Member of Council, Chairman, Glasgow Committee*).
Leigh, A. Lennox, Frodingham.
Levy, Lewis, London.
Lewis, D., Dowlais.
Lewis, David, Gorseinon.
Livesey, James, London.
Longbotham, J., Sheffield.
Louis, *Professor* Henry, Newcastle-on-Tyne

McBEAN, Alex., Wolverhampton.
McGregor, W., Airdrie.
Mackenzie, T. B., Motherwell.
MacLaren, C. F., Wishaw.
McLaren, Walter S. B., London.
McNeil, Charles, Glasgow.
Malmberg, Olof A., Harrow.
Marley, J. E., Hebburn-on-Tyne.
Martin, E. P. (*Past-President*).
Massey, W. H., Twyford.
Maw, W. H., London.
May, George, South Shields.
May, Thomas, Newcastle-on-Tyne.
Mechan, Arthur, Glasgow.
Mechan, Henry, Glasgow.
Melling, J. F., Sheffield and Leeds.
Melling, S., Wigan.
Melling, Thomas, Wigan.
Mellowes, Frank W., Sheffield.
Meyjes, A. C., London.
Middleton, J. T., London.
Mills, Frederick, Ebbw Vale.
Mitchell, G. A., Glasgow.
Mitford, William, Redcar.
Monks, F., Warrington.
Moore, Alfred, London.
Moore, R. T., Glasgow.
Morgan, G. Vaughan, London.
Morgan, P. Vaughan, London.
Morgan, S. Vaughan, London.
Mount-Haes, A., London.
Muirhead, W., Glasgow.
Munro, R. D., Glasgow.
Murray, Matthew, London.

NASH, Thomas, Sheffield.
Needham, C. T., Manchester.
Nesbit, D. M., London.
Nicholson, H., Manchester.
Norris, W. G., Salop.

PAGE, Davidge, London.
Palmer, Henry, Consett.
Parrington, M. W., Sunderland.
Pendred, L., London.
Pendred, Vaughan, London.
Porter, The Hon. R. B., London.
Powell, H. G., F.R.G.S., Wolverhampton.
Prest, S. F., London.
Preston, G. F., Sheffield.
Price-Williams, R., London.

RANDON, W. J., Birmingham.
Reese, Arnold K., Llandaff.
Rennie, Dugald, Jun., Glasgow.
Renton, B. M., Sheffield.
Richards, E. Windsor (*Past-President*).
Riley, James (*Vice-President*).
Roberts, David E., Cardiff.
Robertson, Leslie S., London.
Robinson, F., London.
Robinson, Mark, London.
Robinson, S. J., Sheffield.
Rogerson, John E., Durham.
Rogerson, T. B., Glasgow.
Rollason, James, Birmingham.
Rollin, F. T., Sheffield.
Rosenthal, J. H., London.
Row, O. M., Manchester.

SAHLIN, Axel, Brussels.
Samuel, Herbert, M.P. (*Under Secretary of State for Home Affairs*).
Saniter, E. H., Rotherham.
Sauer, Francis, London.
Scarf, F., West Bromwich.
Schneider, C. P. E. (*Member of Council*).
Schultz, George, London.
Scott, H. Kilburn, London.
Service, A. G., Glasgow.
Shaw, John, Sheffield.
Simons, William, Stoke-on-Trent.
Simpson, F. R., Newcastle-on-Tyne.
Skaife, Walter, London.
Smith, J. T. (*Past-President*), (*Deceased*).
Stead, J. E., F.R.S. (*Member of Council*).
Stoddart, *Colonel* C. J., Rotherham.
Storey, Charles B. C., Lancaster.
Summerson, R. B., Darlington.
Summerson, S. J., Darlington.
Sutherland, D. A., London.
Swan, *Colonel* H. F., Prudhoe-on-Tyne.

TALBOT, Benjamin, Middlesbrough.
Tannett, J. C., Paisley.
Tannett-Walker, A. T. (*Member of Council*).
Taylor, H. F., Briton Ferry.
Taylor, J. S., Birmingham.
Tennent, John, Coatbridge.
Thomas, F. T., Swansea.
Timms, John, Barrow-in-Furness.
Touche, J. E., London.
Turnbull, Alexander, Glasgow.

WALKER, Archibald, Glasgow.
Webb, Henry, Bury.
Westgarth, Tom, Middlesbrough.
While, J. M. (*Member of Council*).
Whitwell, William (*Past-President*).
Widdowson, John H., Manchester.
Willey, G. B., Sheffield.
Williams, Illtyd (*Member of Council*).
Wood, R. N., Newcastle, Staffs.
Worsdell, Wilson, Gateshead-on-Tyne.
Wragg, John D., Burton-on-Trent.
Wright, *Colonel* J. R., Swansea.
Wylie, William, Coatbridge.

YOUNG, Septimus, London.

LONDON MEETING.

The London Reception Committee consisted of those members of the General Reception Committee resident in the London district. The Right Hon. the Lord Mayor of London (Alderman Sir W. Vaughan Morgan, Bart.) kindly consented to act as Chairman. An Executive Committee was formed, consisting of Mr. R. A. Hadfield, Chairman; Sir W. Lloyd Wise, Vice-Chairman; Professor H. Bauerman, Mr. P. B. Brown, Professor W. Gowland, Mr. F. W. Harbord, Mr. A. C. Meyjes, Mr. Matthew Murray, Mr. L. Pendred, Mr. Septimus Young, and Mr. Bennett H. Brough, Secretary. The attendance at the meeting was very large, nearly a thousand members and ladies having registered their names. The Secretary's office was at the Institute headquarters, 28 Victoria Street, London, S.W. The Library of the Institute was temporarily converted into an office for the registration of members, and for the issue of the official programme and the various souvenirs, tickets and printed particulars prepared in connection with the meeting. The Council Room of the Institute was converted into a members' writing-room, while in order to cope with the additional work involved, it was found necessary to secure temporary office accommodation for the conduct of the ordinary work of the Institute. With this object two spacious rooms were rented in the basement of the building, and telephonic communication installed between these offices and the main suite. The badge presented to the members by the Reception Committee was executed in red, white, and blue enamel, and bore the arms of the City of London, with the inscription, "Iron & Steel Institute. American Institute of Mining Engineers, 1906," together with the motto of the City of London.* A counter for the distribution of members' mail was fitted up in the hall of the Institute, and a special staff of messengers and commissionaires was in attendance. In addition to the official detailed programme of the meeting, an illustrated keepsake, having a cover artistically executed in colours, was presented to each member. This literary souvenir was written by Mr. A. C. Meyjes, Member of the Executive Committee, and was profusely illustrated with views of the principal places visited, specially taken for the occasion. An album of views of London was also presented to each of the American guests. The offices remained open during the whole period of the London meeting, and large numbers of the members availed themselves of the facilities provided.

The bulk of the party of members of the American Institute of Mining Engineers, including Captain Robert W. Hunt (President) and Mrs. Hunt, travelled on the *Celtic*, which arrived at Liverpool on Saturday night, July 21, having previously received, in mid-Atlantic, a Marconigram welcoming them to British shores. The visitors travelled down by special train to London on Sunday morning, and were taken to the various hotels at which accommodation had been secured for them. These were the St. Ermin's Hotel, the Westminster Palace Hotel, and the Hotel Cecil.

The proceedings commenced with a reception given by the President and Mrs. Hadfield at the Grafton Galleries, Bond Street, on the evening of Monday, July 23. This entertainment was a great success, and was attended by over a thousand persons. The spacious rooms were beautifully decorated with flowers, and an excellent programme of music was provided by the White Viennese Band, supplemented by a vocal concert. The mornings of Tuesday, Wednesday, and Thursday were devoted to the reading and discussion of papers in the theatre of the Institution of Civil Engineers, Great George Street, Westminster, which had been placed at the disposition of the Iron and Steel Institute for the occasion. On the afternoon of Tuesday, July 24, visits were paid to the National Physical Laboratory, Teddington, to the London County Council's Electric Generating Station, Greenwich, to the Hall of the Worshipful Company of Mercers in Cheapside, and to that of the Worshipful Company of Armourers and

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* The arms consist of the Shield of the City of London, argent, a cross gules in the first quarter, a sword in pale point upwards of the last, with above it the crest (a dragon's sinister wing argent charged with a cross gules), and below it the motto, "Domine dirige nos."

Brasiers in Coleman Street. In the evening a reception was given by the Rt. Hon. the Lord Mayor and Lady Mayoress at the Mansion House. The reception commenced at nine o'clock. The Lord Mayor wore his robes of office, and was attended by the Mace Bearer, the Sword Bearer, the sheriffs, Sir George Smallman and Sir Thomas Bowater, and the high dignitaries of the City of London. The assembled company numbered about twelve hundred ladies and gentlemen, amongst whom were the Duke and Duchess of Norfolk, Lord and Lady Strathcona, Lord and Lady Kelvin, Sir William and Lady White, Sir Howard Vincent, M.P., his Excellency the Spanish Ambassador, Major-General Sir J. Wolfe Murray, Major-General O'Callaghan, the Archdeacon of London, the Lord Mayor of Sheffield, the Lord Chief Justice, Admiral Coerper, Sir Christopher Furness, M.P., and Lady Furness, and Sir Norman and Lady Lockyer. A programme of music was rendered by the band of the Grenadier Guards, and vocal selections of a high order were given in the Egyptian Hall.

On the afternoon of Wednesday, July 25, visits were paid to the works of Messrs. John I. Thornycroft and Co., Ltd., Chiswick, and to the works of Messrs. J. and E. Hall, Ltd., at Dartford. Visits were also paid to the gardens and halls of the Inner and Middle Temples, by kind permission of the Benchers, and to the Victoria and Albert Museum, South Kensington Museum, the Natural History Museum, the Imperial Institute, the Royal Albert Hall, and Kensington Palace (by special permission of His Majesty's Board of Works), tea being served in Kensington Gardens. Members were also invited to witness the test of a reinforced concrete floor at the British Fire Prevention Committee's testing station at Hanover Gate. In the evening the members visited the Imperial-Royal Austrian Exhibition at Earl's Court, by invitation of the Chairman and Directors. The Western Gardens were specially illuminated for the occasion, and a special programme of American music was played. The weather being unusually fine, over a thousand members and ladies availed themselves of the invitation. Visitors were admitted free to the Salt Mine in the Western Gardens, and to the Cave of the Sirens, while the Austrian Commissioners kindly threw open the Tyrol Village, situated in the Empress Theatre.

On the afternoon of Thursday, July 26, a party of the American visitors journeyed to Erith, where they were entertained at luncheon by the President and Council of the Institution of Mining and Metallurgy, and subsequently visited the works of Messrs. Fraser and Chalmers, Ltd., Erith. Other visits were paid to the works of the Associated Portland Cement Manufacturers (1900), Ltd., Northfleet, Kent, to the Lots Road Power Station of the Underground Electric Railways Company of London, Ltd., at Chelsea, and to the Hall of the Worshipful Company of Ironmongers in Fenchurch Street. In the evening over six hundred members and ladies visited the Crystal Palace, on the invitation of the Chairman and Directors of the Company. Two special fast trains left St. Paul's Station of the South-Eastern and Chatham Railway Company. On the arrival at the Crystal Palace, parties were shown over the Crystal Palace School of Practical Engineering by the Principal, Mr. J. W. Wilson, M.Inst.C.E., and the Vice-Principal, Mr. Maurice Wilson, Assoc.M.Inst.C.E. Other parties were taken to inspect the Electric Lighting Station by the chief engineer of the Company, Mr. T. Carr. At 8 P.M. dinner was served in the banqueting hall, by arrangement with Messrs. J. Lyons and Company, Ltd., and boxes of chocolates and cigarettes were presented by the Reception Committee to the ladies and gentlemen present. On the conclusion of the repast a special firework display was given on the Central Terrace by arrangement with Messrs. C. T. Brock and Co. This consisted of the ordinary Thursday night display, specially augmented for the occasion, with set pieces portraying his Majesty the King and President Roosevelt, the British and American flags crossed, and a special device welcoming the American guests on behalf of their hosts, the Iron and Steel Institute. In order that the visitors might view the firework display in comfort, the Chairman and Directors of the Crystal Palace Company placed at their disposition the Gallery over the King's Corridor, and a number of specially reserved windows in the North Museum Gallery. The *fête* terminated at ten o'clock, when the special trains conveyed the members and their guests back to Victoria, which was reached shortly before 11 P.M.

On the morning of Friday, July 27, two special trains left Waterloo Station for Windsor with a party of over six hundred members and friends. On arriving at the royal borough the party proceeded to the Castle, where St. George's Chapel, the White Tower, and the State Apartments of the Castle were visited, special facilities having been graciously granted by his Majesty to enable the visitors to view portions of the Castle not generally shown to the public. Luncheon was served at the White Hart Hotel, after which the members were permitted to view the private gardens and conservatories and the stables. Small parties also visited Eton College and Windsor Old Park. The return journey was made from Windsor at 4.25 P.M.

At midday His Majesty the King graciously received a deputation from the Iron and Steel Institute and the American Institute of Mining Engineers at Buckingham Palace. The members of the American Institute of Mining Engineers, who had the honour of being presented to his Majesty by Mr. R. A. Hadfield, the President of the Iron and Steel Institute, were Captain Robert Hunt (President), Dr. R. W. Raymond (Secretary), Mr. Charles Kirchhoff (Past-President), Mr. Walter Wood (Member of Council), Mr. Joseph Hartshorne (Past-Officer), Mr. Theodore Dwight (Member of Council), Mr. B. F. Fackenthal (Past-Officer), and Mr. Oberlin Smith (Past-Officer).

In the evening the annual dinner of the Iron and Steel Institute was held, by kind permission of the Court of Common Council, in Guildhall. The members were received by the President in the Art Gallery, where the special loan collection of Flemish pictures was much admired. At the dinner Mr. R. A. Hadfield presided, and speeches were delivered by the President, the Lord Mayor, Lord Allerton, Admiral Sir Archibald Douglas, K.C.B., G.C.V.O., the Right Hon. R. B. Haldane, M.P., Sir Hugh Bell, Bart., Lord Stanley of Alderley, Mr. Herbert Samuel, M.P., the Right Hon. Sir James Kitson, Bart., M.P., and by Captain Robert W. Hunt, the President, and Dr. R. W. Raymond, Secretary of the American Institute of Mining Engineers.

The Lady Mayoress and the American ladies were received separately in the Council Chamber by Mrs. Hadfield. The chamber was beautifully decorated with flowers for the occasion. After the reception the ladies were entertained at dinner in two committee-rooms. Mrs. Hadfield took the chair, having on her right hand the Lady Mayoress, and on her left Mrs. Hunt, of Chicago, while the vice-chair was occupied by Lady Kelvin. In the second committee-room Lady Lloyd-Wise presided. On the conclusion of the dinner the ladies proceeded to the gallery of the Guildhall, where they remained until the proceedings terminated, when the company reassembled in the Art Gallery. The library was, by the courtesy of the Library Committee, placed at the disposal of the guests as coffee-room and smoke-room. An artistically designed and executed menu was distributed to each of the guests. The cover, which was printed in colours, bore the arms of the principal nations represented in the membership of the Institute, and a vignette of the Guildhall was shown on the back cover. The string band of the Royal Artillery was in attendance, and the dinner was served in accordance with City traditions by Messrs. Ring and Brymer.

On Saturday, July 28, about 150 members and ladies left Charing Cross by special train for Dover to visit the Dover Harbour Works, on the joint invitation of the Admiralty, Messrs. Coode, Son, and Matthews, the chief engineers, and Messrs. S. Pearson and Son, Ltd., the contractors for the works. The Admiralty pier was first visited, and the party were then conveyed to the Promenade Pier by the steamer *Lady Curzon*, kindly lent by Sir William Crundall. The visitors were entertained at luncheon at the Hotel Burlington, by Sir Weetman D. Pearson, Bart., M.P., and after visiting the East Cliff in the afternoon, were taken to the east arm and south breakwater, and thence by steamer to the Harbour Station.

About eighty members also visited the works of Messrs. Thomas Butlin and Co., Ltd., at Wellingborough, on the invitation of the Chairman and Directors. The party left St. Pancras at 11.15 A.M.. Luncheon was provided in a marquee near the works, and on the conclusion of the visit the return journey was made by special train at 5.20 P.M.

A small party of members of the American Institute of Mining Engineers visited the plant of the South Staffordshire Mond Gas (Power and Heating) Company at Dudley Port, on the invitation of the Chairman and Directors of the Company.

On the morning of Sunday, July 29, a party of members of the American Institute of Mining Engineers attended High Mass at the Roman Catholic Cathedral at Westminster, being subsequently entertained at luncheon by Mr. E. T. Agius.

In the afternoon a number of members and ladies attended divine service at St. Paul's Cathedral, where seats had been reserved for them. The sermon was preached by the Venerable Archdeacon Sinclair, who made special reference to the international character of the Iron and Steel Institute, and its value in strengthening the bonds of union between this country and other nationalities.

Visits were also paid to the Zoological Gardens, where the members and the ladies accompanying them were the guests of Mr. Septimus

Vaughan Morgan. Neatly bound illustrated guide-books to the collections were distributed, and the party was entertained at tea in the gardens. Small parties also visited the Ranelagh Club, Barnes, and the Hurlingham Club, Fulham, the managing committees of these clubs having granted the privilege of admission. During the week hospitality was also dispensed by the committees of management of the Whitehall Club, the St. Stephen's Club, and the Royal Societies' Club, who were good enough to extend the privileges of the clubs to the members of the American Institute of Mining Engineers.

VISIT TO THE NATIONAL PHYSICAL LABORATORY, BUSHEY HOUSE, TEDDINGTON.

On the afternoon of Tuesday, July 24, a party of over 150 members and ladies left Waterloo to visit the National Physical Laboratory, Bushey House, Teddington, on the invitation of Lord Rayleigh, President of the Royal Society, and the Executive Committee of the Laboratory. The visitors were received by Dr. R. T. Glazebrook, F.R.S., Director of the Laboratory, and Mrs. Glazebrook, and were taken in small parties to inspect the various departments by members of the staff. Amongst the objects shown was a lathe, specially designed for the War Office, and intended to adjust and measure the leading screws of lathes, in order to secure uniformity and interchangeability in gun parts made by the department. Much interest was also evinced in the appliances used for testing the magnetic qualities of iron and steel, and in the machines for ascertaining the physical results of shock, and of alternating stresses. An ampère balance designed by Professor Ayrton and the late Professor Viriamu Jones, to serve as the absolute standard of current, also attracted much attention and interest. At the conclusion of the inspection tea was served in the beautiful gardens surrounding the buildings. Mr. Matthew Murray and Mr. Leslie S. Robertson, members of the London Reception Committee, accompanied the visitors from Waterloo, and acted as stewards on the visit.

The National Physical Laboratory was established for the determination of suitable standards of measurement, the preservation and maintenance of such standards, the standardising and testing of instruments for scientific and commercial purposes, the accurate determination of physical constants, and the conduct of physical and engineering research of scientific and commercial importance. The laboratory has been established in what was originally the official residence of the ranger of Bushey Park, which is peculiarly well adapted for experiments requiring stability and an equable temperature. The buildings consist of engineering, electrical and photometric laboratories, and the engine and dynamo-room and boiler-house. There is also a lathe house for the special screw-cutting lathe of the War Office. The Physics division contains the fundamental standards of electrical resistance and electromotive force, including the original coils of the British Association. The verification of thermometers and of meteorological instruments is mainly carried on at Kew. Important researches are carried out at Bushey House in the metallographic department, which is admirably fitted with the appliances required. In the Engineering division researches are in progress on—(*a*) wind pressure, (*b*) the effect of rapid alternations and direct stress on certain materials of construction, (*c*) methods of impact testing, and (*d*) specific heating of superheated steam.

VISIT TO THE LONDON COUNTY COUNCIL ELECTRICITY GENERATING STATION, GREENWICH.

About eighty members assembled at the Westminster pier of the London County Council on July 24, and proceeded by steamboat to Greenwich, under the guidance of Mr. P. B. Brown and Mr. L. Pendred, members of the London Reception Committee. On the outward journey illustrated guide-books and maps relating to the river Thames, presented by the London Reception Committee, were distributed amongst the members taking part in the excursion. Mr. A. L. C. Fell, the chief officer, received the visitors, and conducted them over the station, tea being subsequently served in the offices, after which the party was taken to view the car-sheds at New Cross previous to returning.

The Greenwich Electricity Generating Station, which was opened on May 26, 1906, has been designed to supply sufficient energy for the whole of the tramways worked by the London County Council. It is one of the largest generating stations in the kingdom, and will ultimately have plant amounting to about 52,000 horse-power. The general arrangement of the generating station was designed by the architect to the Council in consultation with the tramways electrical engineer, and the building was erected under the supervision of Mr. W. E. Riley, the Council's architect, and equipped under the supervision of Mr. A. L. C. Fell, the Council's chief officer of tramways, and Mr. Rider, electrical engineer to the Council. The pier and condensing water pipes were designed and erected under the supervision of Mr. Maurice Fitzmaurice, the Council's chief engineer. The site is on the bank of the river at Greenwich, about 250 yards eastward of Greenwich Hospital. There is an area of approximately 3¾ acres. The boiler-house contains twenty-four water-tube boilers of the five-drum Stirling Company's type, arranged in pairs in two rows, with a firing floor between. Each boiler has an evaporative capacity of about 16,300 lb. of water per hour, works at 200 lb. pressure, and is fitted with chain grate-stokers. The engine-room contains four steam generating sets of 3500 kilowatts normal capacity each. The engines are by Messrs. John Musgrave and Sons (Limited), of Bolton, and are of the vertical-horizontal type. Each engine comprises two complete half-engines, one on each side of the generator, consisting of a vertical high-pressure cylinder 33½ in. diameter, and a horizontal low-pressure cylinder, 66 in. diameter. The stroke in each case is 4 ft., and the two connecting rods on the one side of the engine work on to a common overhung crank pin. The engines run at 94 revolutions per minute. The generators are built by the Electric Construction Company (Limited), of Wolverhampton, and are mounted directly on the engine shafts, each generator being erected between the two half-engines of each set. They are all of the revolving-field type, and deliver three-phase current at 6600 volts between phases, and 25 complete cycles per second. The normal output is 3500 kilowatts, or 306 amperes per phase, and 4375 kilowatts on emergency overload. When completed, it is estimated that the station will have cost about £900,000, and the total cost of the pier condensing water pipes, and a wharf wall about 260 feet in length, will be about £53,000.

VISIT TO THE HALL OF THE WORSHIPFUL COMPANY OF ARMOURERS AND BRASIERS.

About a hundred members and ladies, under the guidance of Mr. J. Dewrance, member of the London Reception Committee, visited the Hall of the Worshipful Company of Armourers and Brasiers, Coleman Street, Cheapside, on July 24, on the invitation of the Master and Wardens of the Company. The party were received by some of the office-bearers of the Company. After viewing the fine collection of plate and armour, tea was served in the Livery Hall.

The Hall of the Armourers' Company (known as "The Brethren of the Craft or Mystery of Armorers") was acquired in the seventh year of the reign of Henry VI., A.D. 1428, and comprised "The Dragon" and five shops in Coleman Street. The Hall escaped the Great Fire of London in 1666, and subsequently (additional property having been purchased in London Wall abutting upon the Hall) the premises were much enlarged in 1750–1777. The amalgamation of the Brasiers' Guild with the Company of Armourers took place in 1708, the names of the masters since that date being recorded on the panelling of the Livery Hall. The entire premises were taken down and rebuilt in their present form in 1839–41; but most of the internal arrangements, including the Livery Hall with its adornments and decorative features, were remodelled in 1872, and the paintings and many interesting specimens of the armourers' craft were rearranged as they now are. The names of the benefactors from the time of Eborard Frere, Master of the Company, 1454 and 1455, were also recorded on decorative shields in the main cornice. The principal objects worthy of special notice are the engraved suit of armour worn by Sir Henry Lee, Master of the Armoury in the days of Queen Elizabeth, a portrait of George I. by Vandrebank, a painting representing fine pieces of armour, with assumed portraits of the Earl of Essex and General Monk; Northcote's largest work, representing the entry of Bolingbroke into London prior to his coronation as Henry IV. ("King Richard II.," Act V. Scene 2), the arms of Edward VI. in the wood panel of the chimneypiece, and those of William and Mary in the bronze plaque of the buffet. In the Court dining-room the grant of arms to the Company in the reign of Philip and Mary, 1556, is worthy of notice, especially on account of the sovereign titles accorded to this ill-starred couple. In the drawing-room are the full-length portraits of George II. and Queen Caroline, by Shackleton, the Court painter of his time. They are replicas of the state portraits in the National Portrait Gallery. In the same room are two celebrated English pictures, purchased by the

Company at the sale of the Boydell Shakespearean collection in 1805. Both these works, as well as the Northcote picture already mentioned, which was purchased at the same time, have been engraved. On the walls may be seen a few notable specimens of blades and other weapons, as well as the processional axes of the mediæval Electors of Saxony, as Masters of the Mining Guild; and in the case at the end of the room are a variety of modern specimens of the brasiers' and metal workers' crafts, obtained by the Company in 1889, 1890, and 1891, when exhibitions were held in the Hall for the purpose of promoting the brasiers' art, and giving encouragement to apprentices and craftsmen. In the Court Room is a portrait of Roger Tyndale, bequeathed by his will in 1587. As he was Master of the Company in 1559, 1567, and 1577, and one of Queen Elizabeth's Gentlemen-at-Arms, this picture possesses historical interest. In the cases on the walls are a few manuscripts worthy of notice, some of which relate to the conveyance of lands and tenements to the Company in the fourteenth and fifteenth centuries.

VISIT TO THE HALL OF THE WORSHIPFUL COMPANY OF MERCERS.

A large party numbering about 200 persons, under the guidance of Mr. F. W. Harbord and Mr. E. F. Law, visited Mercers' Hall, Cheapside, on July 24, on the invitation of the Master and Wardens. The visitors were received by several of the Office-bearers of the Company, and were subsequently entertained at tea in the Livery Hall.

The Hall of the Mercers' Company, the first on the list of the twelve Great Guilds of London, is in Cheapside, between Ironmonger Lane and Old Jewry. The Mercers were recognised as a Guild in 1172, and incorporated as "The Men of the Mystery of Mercery" in 1393. After the Great Fire, the Hall was rebuilt, in 1672, from the designs of Sir C. Wren. The Company possess a portrait of Dean Colet, founder of St. Paul's School, the management of which he left to the Mercers' Company; a portrait of Sir Thomas Gresham, founder of the Royal Exchange, a member of the Company; and the very fine Leigh Cup of 1499, the oldest and one of the finest pieces of plate in the City. Whittington, the famous "four times Mayor of London," was a member of the Company, and Queen Elizabeth was a "free sister" of the Company. The visitors were shown the beautiful chapel (also built by Wren), which was greatly admired, as was also the magnificent plate for which this Company is famous.

VISIT TO THE HALL OF THE WORSHIPFUL COMPANY OF GROCERS.

Members also visited the Hall of the Grocers' Company in Princes Street, on the invitation of the Master and Wardens of the Worshipful Company which, in point of precedence, ranks second amongst the twelve Great Companies. It was incorporated in 1345, and was formerly known as the "Pepperers," the foundation reciting that "to the honour of God, and the Virgin Mary, St. Anthony, and All Saints," the Company was established "for love and unity," to maintain and keep themselves together.

VISIT TO THE WORKS OF JOHN I. THORNYCROFT AND CO., LTD., CHISWICK.

Over a hundred members journeyed to Turnham Green on the afternoon of Wednesday, July 25, to visit the works of Messrs. John I. Thornycroft and Co., Ltd., Chiswick. Sir W. Lloyd Wise, Vice-Chairman of the London Reception Committee, and Mr. L. Levy (member of the Committee), acted as stewards on this occasion. The visitors were conveyed in motor cars from the station at Turnham Green to the works, where they were received by Sir John Thornycroft and members of his staff. After inspecting the works the party was entertained at tea. On the conclusion of the visit, Sir W. Lloyd Wise proposed a vote of thanks to the firm, which Mr. Walter Wood, of Philadelphia, seconded on behalf of the American members present. The vote was acknowledged by Sir John Thornycroft on behalf of the firm.

About the year 1860 Mr. (now Sir) John Isaac Thornycroft, then only seventeen years of age, constructed, from his own designs, the steam launch *Nautilus*, the principal dimensions of which were:

Length	36 feet.
Beam	5 feet 10 inches,

giving a speed of twelve miles. The young engineer's vessel was a complete success, and fully justified the general interest it evoked. In 1864, having attained his majority, he founded the shipbuilding yard at Chiswick which bears his name. Here he began to build small launches, and to concentrate his energies on the further development of the principles of construction, for which he had already established a reputation. Amongst the vessels constructed by Mr. Thornycroft in these early days was the launch *Miranda*, the importance of which may be gathered from the fact that Lord Armstrong and the late Sir Frederick Bramwell journeyed specially to Chiswick to witness its evolutions, and the latter, in 1872, discussed the *Miranda* in a paper contributed to the Institution of Naval Architects. Amongst the important patents taken out was that for the Thornycroft screw propeller in 1873. These propellers are now recognised to be perhaps the most efficient in the world, and, from the date of the invention, the Chiswick Works have continually received large orders for propellers. As an instance of the efficiency of the Thornycroft propeller it may be mentioned that the principal racing motor boats on the Continent are fitted with them. His reputation as an inventor was further enhanced by the completion of the *Gitana*, a vessel which had a closed stokehold with forced draught, locomotive boilers, and three-cylinder engines, and which united strength with lightness to what was, until then, an unknown degree. In 1873 the late Mr. John Donaldson joined Mr. Thornycroft, and the business was carried on by them in partnership until Mr. Donaldson's death in October 1899. The earlier part of this period was spent to a great extent in transferring the principles of the *Gitana* to the torpedo boat, an industry of which Sir John Thornycroft is the founder. Amongst his inventions of this period may be mentioned the Thornycroft double rudder, the screw turbine for shallow draft vessels, and the Thornycroft water-tube boiler, now in use to the extent of over one million indicated horse-power. Sir John also designed and constructed, in conjunction with his sons, steam waggons, shortly before the passing of the Act which legalised their use in this country, and in 1896 the Thornycroft Steam Waggon Company was founded for the purpose of carrying on the manufacture of these vehicles. Later on the Company designed steam waggons which in competition gained several gold medals, and in December 1901 gained the £500 prize offered by the War Office for the best motor-driven vehicle suitable for military purposes. Shortly after this, the Thornycroft Steam Waggon Company commenced to manufacture the now well-known Thornycroft petrol-driven commercial vehicles and touring cars. The name of "Thornycroft" is, however, chiefly associated with the well-known water-tube boiler. Of course the principles of this invention were, theoretically, already known, but to Sir John Thornycroft belongs the distinction of perfecting the scheme and making the utilisation of the water-tube boiler advantageous. As will be remembered, the boiler was shortly afterwards adopted by the Admiralty on an extensive scale, and it is now used in the navies of the United Kingdom, Germany, Russia, Austria, the United States, Italy, Sweden, and Japan, and is patented in these countries and elsewhere. In 1901 the business was formed into a Limited Liability Company. During the following twelve months the Company spent a considerable sum in reorganising the shops, and laying down new machinery. The year 1904 was marked by great development and expansion. A new branch was established for the manufacture of motors for marine purposes, and the hitherto distinct companies of John I. Thornycroft and Company, Limited, and the Thornycroft Steam Waggon Company, Limited, were amalgamated. Further, in view of the constant tendency on the part of the British Admiralty to increase the size of the torpedo boat destroyer, the type then in use being practically the largest vessel that could be constructed at the Chiswick yard, the company considered it advisable to acquire more convenient premises for this branch of work, and accordingly entered into agreement with Messrs. Mordey, Carney (Southampton), Limited, for the purchase of their yard at Woolston, Southampton, the intention being to gradually remove the torpedo boat work to Southampton, and to develop the marine engine and motor engine work at Chiswick. In addition to other advantages, the Company now have docking facilities at Southampton for vessels of large size. The Company have recently secured the patent rights of the Capitaine system of marine producer-gas plant, and at the motor yacht reliability trials at Southampton in August last, in addition to several silver medals for their petrol and oil-propelled motor boats, they were awarded a special gold medal for their successful application of this system. It only remains to be said that the firm have gained a world-wide reputation for their torpedo boats, destroyers, shallow draft steamers, motor boats, cars and commercial vehicles, and for the general excellence of their work.

VISIT TO THE WORKS OF J. AND E. HALL, LIMITED, DARTFORD.

On July 25 a party of members and friends assembled at Charing Cross Station, where they were met by the stewards, Messrs. G. Schultz and F. A. Willcox. On reaching Dartford they were received in the pattern shop of the works by the Chairman of the Company, Mr. Everard Hesketh, and his fellow-directors, Messrs. B. Godfrey, H. J. Ward, F. W. Wright, and J. de Saugy. Mr. Hesketh welcomed the guests, and briefly explained to them that the works were at the time entirely devoted to the manufacture of carbonic anhydride refrigerating machinery, which they would be shown in every stage of manufacture, and that in addition they had lately put down a plant for the manufacture of the chassis of automobiles, which would be open to inspection. He hoped that, in view of the recent development of the Gayley dry-blast process, the refrigerating department would be of interest. In order to enable them to fully appreciate the effect of the Gayley process on the atmosphere, he had had erected an experimental air-drying plant, which they would see in actual operation. The members were then conducted through the works in parties. The guides attached to each party explained the operations carried on in the pattern shop, iron and brass foundries, machine shop and erecting shop in the manufacture of the compressing plants.

The visitors were particularly interested in the special furnaces for melting brass and the intricate nature of many of the brass castings, and in the arrangement of the foundries for making both large and small castings. In the machine shop they saw a number and variety of high-speed modern machines, and more especially a machine which was boring a hole 6 inches diameter in a solid forged compressor of high carbon steel at the rate of 12 inches per hour, and machining the other end at the same time. In the manufacture of the evaporators and condensers they saw iron pipes electrically welded into lengths of several hundred feet and then bent into coils for evaporators and condensers, or made into grids for circulating brine in cold chambers. In this department they also saw the coils of evaporators and condensers and all other parts of the compressing machines tested to 3000 lbs. per square inch by hydraulic pressure, and afterwards by air pressure, when submerged in order to detect the slightest porosity. In the erecting shop there were completed machines from 120 tons to 6 cwts. refrigerating capacity per day, and amongst these several duplex type machines of various sizes used for meat preservation, one of them forming part of the installation of the largest meat-carrying vessel yet built. Also to enable the members to appreciate the action of the refrigerating machine a 20-ton machine was shown running under ordinary conditions, and a 10-ton machine undergoing its thermal guarantee trials. The visitors proceeded from the erecting shop to the experimental air-drying plant. This plant illustrated the drying of air by means of refrigeration, and in fact was on a small scale the type of plant which is used for drying the air for blast-furnaces. A carbonic acid refrigerating machine was cooling brine, which by means of centrifugal pumps was circulated through a series of grids over which air was driven. There were arrangements for varying both the temperature and humidity of the air passing through the air cooler. The arrangement also included a regenerator and governor by means of which the cold dry air was used for partly cooling the incoming moist air before it reached the grids connected to the refrigerating machine, and this generator was arranged to maintain the exit temperature of the dry air constant, while the temperature of the incoming air varied. On leaving the works the guests proceeded to the North Pole Restaurant, an establishment built by the Chairman of the Company for the purpose of providing wholesome meals and comfortable surroundings for the workmen. Mr. James Riley, Vice-President, proposed a vote of thanks to Mr. Hesketh and his fellow-directors and staff for their kindness and hospitality. He felt that what they had seen would be of great value, more especially in view of the important position refrigeration would, in the future, probably take in the smelting of pig iron. The motion was seconded by Mr. E. Saladin and acknowledged by Mr. Hesketh.

The firm of J. and E. Hall, Ltd., was founded in 1785 by Mr. John Hall, and in 1900 was formed into a limited company. In 1878 the management first began to devote attention to refrigerating machinery, which is now their sole concern, and in 1888 brought out the Carbonic Dioxide Refrigerating Machine, which has since been very largely adopted in the Mercantile Marine. The immense impetus which the demand for this class of machinery has received of late years has necessitated the laying down of extensive new plant and considerable enlargement of the works. These works were amongst the first in this country to adopt the Electric Welding Process, which they have now used for many years for the manufacture of coils required for refrigerating machines, the amount of 1½-inch pipe welded up per day often amounting to 4000 feet run. The works include iron and brass foundries, pattern and carpenters' shops, machine shops, brass finishers' shop, coppersmiths' shop, smithy, coil-making and casing shop, and erecting shop, the latter being specially laid out to enable machines to be run after completion, when each one is tested and the amount of refrigerating work which it will do accurately measured. Amongst the special tools is one designed for machining the steel compressors of the refrigerating machines, which are bored from solid forgings of high carbon steel. The works are driven throughout, as well as lighted, by electricity generated in their own power-house by two Willans and Robinson's engines, direct coupled to E. C. dynamos of 220 kilowatts. In the same power-house are situated an air-compressor which gives the power for working pneumatic tools, some very high-pressure air-compressors used for testing all parts of carbonic anhydride machines subject to the pressure of that gas, also electric welding machines and various pumps for working hydraulic tools and testing.

An illustrated description of the works has appeared in *Engineering*, vol. lxxxii. p. 76.

VISIT TO ERITH.

On the afternoon of Thursday, July 26, a party of the members of the American Institute of Mining Engineers and of the London Reception Committee journeyed by special train to Erith, where they were entertained at luncheon by invitation of the President and Council of the Institution of Mining and Metallurgy. The chair was taken by Mr. Arthur C. Claudet, President, and at the conclusion of the repast he extended a welcome to the American visitors on behalf of the Institution. Mr. Charles Kirchhoff returned thanks.

A visit was subsequently paid to the works of Messrs. Fraser and Chalmers, Ltd., adjoining which the luncheon marquee had been erected. After inspecting the works the visitors were entertained at tea by the Company, and returned to town by special train at 5 P.M.

The works of Messrs. Fraser and Chalmers, Ltd., are situated on the Thames at Erith, Kent, with wharf and river shipment, and connection with the lines of the South-Eastern and Chatham Railway. The shops were begun in 1892, and have been gradually enlarged and added to until now a force of over 1200 men is employed. Until 1901 the Company also owned works in Chicago, and shipments were made partly from America and partly from Erith. At present the whole of the Company's manufacture is concentrated at Erith. The English Company was formed for the purpose of establishing in England the manufacture of high-class modern mining machinery, and as a first step thereto the then well-known American business of Fraser and Chalmers was bought, and later was sold when it had served its purpose of building up the English trade. The shops are fitted with modern tools of the best types built in England, United States, and Germany, and special provision has been made for the erection and testing of large engines, pumps, and compressors. The latest addition has been for the accommodation of tools and testing floor for the manufacture of high and low-pressure steam turbines of the Rateau type. The large area of the boiler shop allows of the complete erection under cover of the largest size of gold dredges. Among the great variety of machinery which is made at Erith, the following may be mentioned as receiving special attention and representing special experience in manufacture: Driving engines, compound hoisting engines, Whiting hoists, Riedler and Gutermuth pumps and compressors, crushers, stamp mills, grinding pans, tube mills, cyanide plants, concentration mills, Wilfley tables and slimers, Frue vanners, smelting-furnaces, Bessemer converter plants, roasting-furnaces, Blaisdell excavators, continuous filters, coal screening and washing plants, boilers, Rateau steam turbines, Rateau centrifugal pumps and turbo-compressors, ventilator fans, diamond washing plants, heavy American type of gold dredges, and the necessary accessories for the various plants.

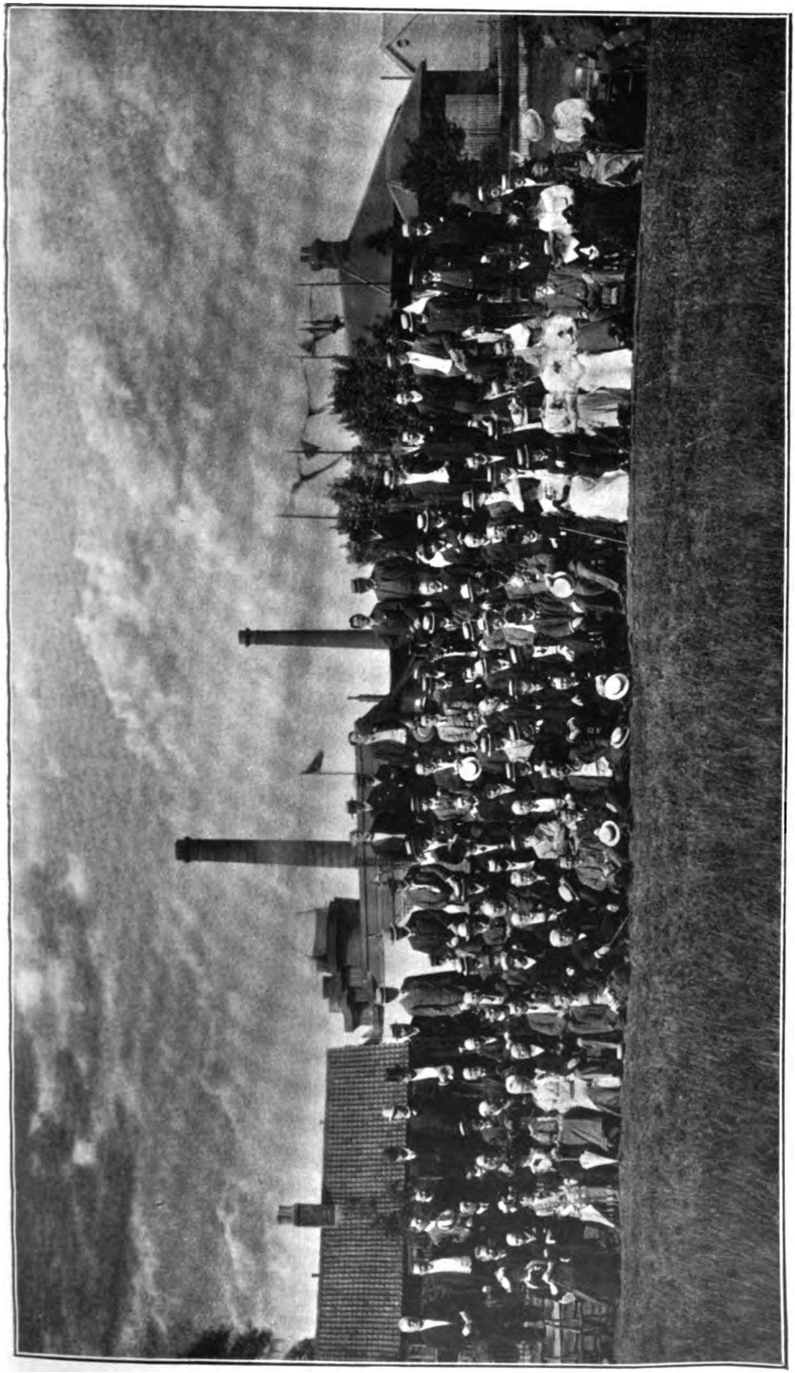
VISIT TO NORTHFLEET.

On July 26 about fifty members journeyed from Charing Cross Station to Northfleet on the invitation of the Chairman and Directors of the

PLATE LIII

Visit to Dover.

PLATE LIV



VISIT TO WELLINGBOROUGH.

Associated Portland Cement Manufacturers (1900), Ltd., to visit their Knight, Bevan and Sturge works at Northfleet. Mr. H. Kelway-Bamber, member of the London Reception Committee, acted as steward, and after visiting the works the visitors were entertained at tea by the Company.

Northfleet may fairly be called the cradle of the Portland cement industry, for it was here that the earliest works were erected by the younger Aspdin about the year 1828. These works, owned for a number of years by Messrs. Robins and Company, Limited, passed, with many others, into the hands of their present owners in the year 1900. In close proximity to them are the works formerly owned by Messrs. John Bazley White and Brothers, Ltd., and by Messrs. Knight, Bevan and Sturge, who were the first to distribute the new product in foreign countries, and whose trademarks have acquired a world-wide reputation. About the same time other works were started by Messrs. Hilton and Anderson at Faversham (Kent), and gradually the production of Portland cement in the valleys of the Thames and Medway has extended until it now reaches the substantial total of about 2,000,000 tons per annum, and the major portion of this output is made at works now belonging to the Associated Portland Cement Manufacturers (1900), Ltd. These include the works and businesses belonging to twenty-two firms or companies, including the oldest established and best known in the world, among which are :—John Bazley White and Brothers, Ltd.; Hilton, Anderson, Brooks and Company, Ltd.; Knight, Bevan and Sturge; Burham Brick, Lime, and Cement Company, Ltd.; Francis and Company, Ltd.; London Portland Cement Company, Ltd.; Gibbs and Company, Ltd. The various properties owned by the Company in the valleys of the Thames and Medway alone cover 4000 acres. The river frontages with their extensive docks and wharves are more than nine miles in length, and a fleet of 200 vessels (steam tugs, lighters, and barges) owned by the Company is daily employed for the transport of materials and products to and from the various works. Several of the works have equal facilities for delivery by rail and water. Central foundries and engineering shops have been erected at Northfleet and Frindsbury, near Rochester, to deal promptly with any heavy repairs to machinery or additions to plant which cannot be conveniently carried out at the numerous local workshops. The cask-making machinery at the Company's cooperages is capable of turning out upwards of three million barrels a year, chiefly for export, the greater part of the cement for the home trade being supplied in sacks. At the numerous factories every approved method of mixing the raw materials and burning and grinding the cement may be seen in operation, and careful experiments are being continually made to test any new process which may lead to improvement in quality or economy of production. The largest works on the Thames are situated at Northfleet, Swanscombe, and Grays, and on the Medway at Rochester, Halling, and Burham. The Company employs fully 6000 people, and the annual capacity of its works will shortly be brought up to approximately one and a half million tons.

VISIT TO CHELSEA POWER STATION.

About fifty members assembled at St. Ermin's Hotel, Westminster, on July 26, where they were met by Mr. P. B. Brown, member of the London Reception Committee, and taken under his guidance, in brakes, to Chelsea, to visit the generating station of the Underground Electric Railways Company of London, Ltd., at Lots Road, Chelsea. The visitors were received on arrival by Mr. J. R. Chapman, the chief engineer, and Mr. Towle, who conducted them over the station. On the conclusion of the visit, Mr. J. E. Touche thanked the chief engineer on behalf of those present, and the latter responded briefly. On the return drive a halt was made at the Tate Gallery of British Art, where the members inspected the Art collections previous to returning to their hotels.

The new power-house of the Underground Electric Railways Company of London occupies a site of 3·67 acres of land, and is built on a self-supporting steel frame weighing about 6000 tons. There are sixty-four water-tube boilers arranged two storeys high, and floor space is provided for sixteen additional boilers. Each boiler has 5212 square feet of heating surface and 672 square feet of superheating surface, and is equipped with chain grate-stokers. The main generating set consists of a horizontal turbine engine running at 1000 revolutions per minute, and a three-phase generator wound for 11,000 volts 33⅓ cycles. There are eight such sets with floor space for two more of the same size and one of half size. The normal rating of each generator is 5500 kilowatts, but they will carry an overload of 50 per cent. for two hours at practically the same steam consumption per kilowatt-hour. The coal storage capacity of the bunkers is 15,000 tons, and the daily consumption will reach 800 tons.

VISIT TO THE HALL OF THE WORSHIPFUL COMPANY OF IRONMONGERS.

Over 150 members assembled on July 26 at St. James' Park Station and proceeded to Mark Lane, under the guidance of Mr. A. C. Meyjes, member of the London Reception Committee, who conducted them to the hall of the Worshipful Company of Ironmongers, which was visited on the invitation of the Master and Wardens of the Company, by whom they were received on their arrival. The visitors proceeded to the banqueting hall, where the honorary librarian, Mr. E. A. Nicholls, gave an interesting address dealing with the origin and history of the Guild, and described the chief points of interest in the building, and the portraits and exhibits. Tea was afterwards served in the banqueting hall, and at the conclusion of the visit, Captain Hunt, President of the American Institute of Mining Engineers, proposed a vote of thanks to the Company, which was suitably acknowledged by the Master.

The present Ironmongers' Hall is believed to be the third which has stood on the site, the first hall having been built somewhere about the year 1457, in the reign of Henry VI. The second hall, which was built during the reign of Elizabeth, in 1587, narrowly escaped destruction by the

Great Fire of 1666. It was superseded in 1745 by the present hall, built in the Palladian style, with a vestibule with handsome columns and groined ceiling and a beautiful banqueting hall, which, for general effect, is not surpassed by any similar chamber in the city of London. The plate of the Company includes several specimens of interest, dating from the fifteenth and sixteenth centuries, and the library possesses a fine edition of the "Compleat Angler" by Isaac Walton, a former warden of the Guild, whose portrait hangs in the banqueting hall. One of the most interesting objects in the possession of the Company is Ironmonger's Pall, a beautiful work of art, consisting of cloth of gold richly embroidered.

The Guild ranks among the twelve Great City Companies, and was incorporated as far back as 1463. Long before those days, however, it had existed as a voluntary brotherhood of members of the iron trade, in fact there is a reference to ironmongers in the City records of as early a date as 1300, when the *Ferones*, or dealers in iron, complained to the authorities that the smiths of the wealds were supplying irons, for cartwheels, of much shorter length than ancient usage allowed. Whereupon certain ironmongers bearing the lordly names of Robert de Paddington and John de Wymondcham were empowered to seize any offending irons. The Company has more than once been concerned in "Plantation" schemes on a small scale, and it is on record that in the reign of James I. it took part, with other companies, in a scheme for colonising Virginia, "to ease the Cittie and suburbs of a swarme of unnecessarie inmates as a continuall cause of dearth and famine, and the verie origenall of all plagues." Another plantation scheme, in Ireland, brought to the Company the Manor of Lizard, near Coleraine, hence the lizards which serve as supporters of the Company's coat-of-arms.

Visit to Dover Harbour Works.

On the morning of Saturday, 28th July, a party numbering nearly 200 left Charing Cross by special train to visit Dover Harbour Works, by kind permission of the Admiralty, Messrs. Coode, Son, and Matthews, chief engineers, and Messrs. S. Pearson and Son, Ltd., the contractors for the work. The party left Charing Cross at 9.45, and arrived at Dover at 11.40, where they were met by their hosts and conducted to the Harbour Works, which were then inspected. At 12.45 the party left the Admiralty Pier by the steamer *Lady Curzon*, which had been kindly lent for the occasion by Sir William Crundall, and were taken to the Promenade Pier, whence they proceeded to the Hotel Burlington, where they were entertained at luncheon on the invitation of Sir Weetman D. Pearson, Bart., M.P., and the directors of Messrs. S. Pearson and Son, Ltd. Sir Weetman Pearson took the chair, and expressed the pleasure which he and his co-directors felt at the visit of the members of the two Institutes. Mr. E. W. Moir gave some interesting particulars respecting the operations which, he said, represented six years' work, but had been frequently retarded by the heavy gales and tides experienced. Captain Hunt, President of the American Institute of

Mining Engineers, proposed a vote of thanks to Sir Weetman Pearson and his co-directors, which was seconded by Dr. Raymond, Secretary of the American Institute of Mining Engineers, and the Chairman briefly replied. The party left Dover for Charing Cross at 4.30.

The new harbour, which, when completed, will be the largest artificial harbour in the world, is being built for the Admiralty from plans drawn by Messrs. Coode, Son, and Matthews, the work itself being carried out by Messrs. S. Pearson and Son, Limited. The operations entail the extension of the present Admiralty Pier 2000 feet, the building of a new arm out from the point beyond the old convict prison, and the erection of an island breakwater. They were commenced in March 1898, and it is hoped that they will be completed in 1908. The piers and breakwaters now under construction will enclose an area exceeding 1 square mile. The southern breakwater is 4200 feet long, and the western arm 3320 feet long. The extension of the Admiralty Pier is now practically completed. The cost of the works so far has been four million pounds. The harbour works are described and illustrated in *Cassier's Magazine* (August 1903), in the *Engineering Review* (October 1905), and in *Public Works* (April 1905).

VISIT TO WELLINGBOROUGH.

About one hundred members and ladies journeyed by special train from St. Pancras on the morning of Saturday, 28th July, to visit the works of Messrs. Thomas Butlin and Company, Ltd., Wellingborough. The party was met at St. Pancras by the Chairman, Mr. W. H. Butlin, who travelled with them to the works. The party reached Wellingborough at about 12.30, where they were met by the directors of the firm, Mr. F. J. Butlin, Mr. W. Wright, J.P., and Mr. Alfred Docker, assisted by Mr. T. A. Stimson.

The proceedings commenced with the opening of a club-room which the management had provided for the workmen. The Mayor of Northampton officiated, and declared the room open. The party then proceeded to the blast-furnaces, where they witnessed a tap, and were subsequently taken to the foundry, where the process of direct castings was shown in operation. After having been photographed the party were entertained at luncheon in a tastefully decorated marquee adjoining the works. During the luncheon the Blue Hungarian Band played a selection of music, and enamelled cigarette cases and match-boxes were presented to the gentlemen present. The Chairman proposed the usual loyal toasts, coupled with the name of the President of the United States. He then proposed the toast of the guests, expressing the pleasure he had in welcoming on behalf of his co-directors the members of the American Institute of Mining Engineers, who had shown such hospitality to the members of the Institute on the occasion of the visits to America in 1890 and in 1904. The Hon. Robert J. Wynne, Consul-General for the United States, Professor H. Bauerman, and Mr. E. Saladin responded. Mr. J. E. Touche proposed the toast of the County and Borough of Northampton, which was acknowledged by Councillor S. G. Stockford Sackville, Chairman of the Borough of Northampton, and by the Mayor of Northampton (Councillor J. Manfield). Speeches were also made by Alderman S. S. Campion, by Mr. Rouse Orlebar, J.P., and by Mr. Harry Foster, and the vote of thanks to the Chairman was proposed by Mr. J. S. Jeans. The party left Wellingborough at 5.30.

Messrs. Butlin and Company were the first firm to smelt Northamptonshire iron ores at the original works of its founder, situated in the town of Wellingborough, during the month of February 1852. A sample of the first ore used is preserved in the Company's offices, whilst samples of ore were shown at the Exhibition of 1851 by Mr. Blackwell. In 1866 the Company transferred their works to the present convenient site on the Midland, and London and North-Western Railways, within sixty-four miles of the metropolis. The Company has four blast-furnaces, 55 feet in height, a pair of which produce 700 tons of foundry and forge pigs weekly from the local ores, which are carefully smelted and scientifically mixed, and the plant arranged, not so much with the idea of producing quantity but rather quality, with uniformity of product. Recently a foundry has been added to the plant, and special attention has been directed to producing improved direct castings. The results have been so highly satisfactory as to leave in many cases no necessity for the employment of the cupola. Thus tunnel segments for tube railways and various other machinable castings are produced of a uniform quality to the extent of 100 to 140 tons weekly, the aim being to scientifically select the ores and then to combine them in accordance with their chemical composition, and so attain what is required instead of mixing different varieties of pig, with a similar end in view, before introduction into the cupola. By these means uniformity of product, economy in production, and an improved quality are the results, whilst the near proximity to the London market offers a further economy in carriage to one of the chief markets of consumption, as in the case of the London tube railways. It should be noted that there is a ready sale both locally and in the London market for the blast-furnace slag, which, owing to its correct chemical composition and uniform quality, is largely used for macadamising roads in the place of granite, and with greater economy, as well as for artificial flooring and decorative work in private and public buildings, such as that made by the Metallic Paving and Artificial Stone Company, Ltd., London.

An illustrated description of the Wellingborough works has appeared in the *Iron and Coal Trades Review* for July 27, 1906, and in the special number of the *Ironmonger* for August 4.

NORTHERN TOUR.

For the week following the Joint Meeting of the Iron and Steel Institute and the American Institute of Mining Engineers, a tour to iron-making districts was organised by the Iron and Steel Institute. The following was the general itinerary:—

Monday, July 30	Leave London	9.50 a.m.
	Arrive York	1.53 p.m.
Tuesday, July 31	Leave York	8.20 a.m.
	Arrive Middlesbrough	9.40 a.m.
	Leave Middlesbrough	3.50 p.m.
	Arrive Durham	4.36 p.m.
	Leave Durham	7.0 p.m.
	Arrive Newcastle-on-Tyne	7.22 p.m.
Wednesday, August 1	In Newcastle-on-Tyne.	
Thursday, August 2	Leave Newcastle-on-Tyne	6.5 p.m.
	Arrive Glasgow	10.10 p.m.
Friday, August 3	In Glasgow.	
Saturday, August 4	Leave Glasgow	9.30 a.m.
	Arrive Edinburgh	10.40 a.m.

A programme of the tour, in pamphlet form, was presented to each visitor.

As an alternative to the tour organised by the Iron and Steel Institute, the American visitors were invited by the President (Mr. E. P. Martin) and Council of the Institution of Mechanical Engineers to take part in the Cardiff meeting, which began on Monday, July 30, and ended on August 3. Several of the visitors availed themselves of this cordial invitation.

On Monday, July 30, a party numbering about 125 members and ladies left King's Cross Station at 10 A.M. by special train for York. The party was accompanied by Captain R. W. Hunt, President of the American Institute of Mining Engineers, and Mrs. Hunt, and included Dr. R. W. Raymond, New York (Secretary), Mr. J. Hartshorne, Pottstown (Past-President), Mr. Chas. Kirchhoff, New York (Past-President), Mr. Theodore Dwight, New York (Member of Council), Mr. B. F. Fackenthal, jun., Easton (Past Officer), Mr. Oberlin Smith, Bridgeton (Past Officer), Mr. Walter Wood, Philadelphia (Member of Council), and Dr. Jos. Struthers, New York (Assistant Secretary. The following gentlemen accompanied the party as stewards:—Professor

H. Bauerman, Messrs. W. F. Cheesewright, D. A. Louis, A. C. Meyjes, L. Pendred, and Hubert S. Thomas. The following officials of the Iron and Steel Institute accompanied the party throughout the tour:—Mr. Bennett H. Brough (Secretary), Mr. L. P. Sidney (Chief Assistant), and Mr. A. Dowd and the late Mr. J. W. Hallett.

VISIT TO YORK.

The party reached York at 1.53, and at once proceeded to the Station Hotel, which was the official headquarters during the stay at York. After luncheon had been served, the party proceeded to visit York Minster, where they were taken to view the Choir and the Crypt. York Minster dates back from the seventh century, when the Saxon King Edward, who had embraced Christianity, was baptized by Paulinus in a small wooden church erected for this purpose on the site of the present Minster. After undergoing many vicissitudes, the Cathedral which now dominates the ancient city was commenced in 1083, and the west front was finished in 1338. In 1829 the Choir was destroyed by fire, and was restored in 1832. The present fabric is in somewhat bad repair, as the stone of which it is built is of a rather perishable nature compared with that used in the construction of most of the cathedrals of contemporary date. York Minster is remarkable for possessing some of the finest windows of any cathedral in this country. The total length of the cathedral is 519 feet, and the length of the nave 225 feet. The central tower, which is the largest tower of its kind in England, is 198 feet high and 65 feet square. After visiting the Cathedral the party dispersed, some of the members finding their way to the Castle, and others proceeding down Deansgate to visit Bootham Bar. A number of members also visited the interesting old Guildhall and Council Chamber situated in Coney Street. The Guildhall, which owes its origin to the Guild of St. Christopher, dates from 1446, and is built in the Perpendicular Gothic style. A guide-book to York and an illustrated brochure containing a description of York Minster were presented to those taking part in the visit.

On returning to the hotel, the party was met by a deputation from the Tees-side Reception Committee, consisting of Mr. James Riley (Vice-President), Mr. Tom Westgarth, members of the Executive Committee, and Sir Hugh Gilzean Reid. Speeches of welcome were delivered by these gentlemen during the dinner, and were acknowledged on behalf of the American visitors by Captain R. W. Hunt. The male members of the party left York on the following morning by a special train, which had been kindly provided by the North Eastern Railway Company, who, while the party was travelling in the area controlled by the Company, generously afforded free travelling facilities.

VISIT TO CADEBY MAIN COLLIERY.

On the route to York a party of members of the American Institute of Mining Engineers left the special train at Doncaster and proceeded to the

Conisborough Station to visit the Cadeby Main Colliery, under the guidance of Mr. W. H. Chambers, the managing director of the Denaby and Cadeby Main Collieries, Ltd., Mr. H. S. Witty, the manager, and Mr. Williamson, the engineer. On the conclusion of the visit, Mr. D. A. Louis, who accompanied the party, proposed a vote of thanks on behalf of the Iron and Steel Institute to Mr. Chambers, as the representative of the Denaby and Cadeby Main Collieries Company. Professor A. Sauveur (Boston) expressed thanks on behalf of the American visitors. The party subsequently left Conisborough Station at 4.55, reaching York at 6.44.

Cadeby Main Colliery lies in the Don Valley between Rotherham and Doncaster, near the ancient and historic Conisborough Castle, about five miles south-west of Doncaster. The colliery belongs to the Denaby and Cadeby Main Collieries, Ltd., and employs about 4000 men and boys. There are two shafts, No. 1 (down-cast), and No. 2 (upcast), through both of which coal is wound. No. 1 shaft is 763 yards deep, No. 2 shaft 750 yards; both shafts are 16 feet diameter finished. The winding engines are practically the same for each shaft, and are coupled engines, double-acting, the size of engine being 45 inch diameter cylinders by 7 foot stroke; steam pressure, 80 lbs. per square inch. Revolutions per wind, $24\frac{3}{4}$. Drum, conical, 21 to 33 feet diameter, 16 feet wide. Rope, $1\frac{15}{16}$ inch diameter (about 6 inches circumference), weighing 7 tons 6 cwt. Ormerod's safety-hook is used, and the rope is attached to the cage by patent spring, weight of cage and spring being 6 tons 13 cwt. The cages are four-decked, carrying two 10 cwt. tubs on each deck, hence weight of coal per wind = 4 tons. The time taken per wind is 55 seconds; time for changing or decking, 5 seconds. All the four decks are changed simultaneously by hydraulic machinery. The hydraulic apparatus was designed by Mr. W. H. Chambers. The total quantity of coal wound up per day of fourteen hours from one shaft is 3360 tons. The shafts are fitted with steel rail guides. The headgears are built of iron and steel lattice, that over No. 1 shaft being 90 feet high, whilst No. 2 headgear is 103 feet high. The pulleys at each shaft are 16 feet diameter. The pit banks are supported on columns, so that the largest waggons can be run under the screens. During the wind in the shaft, the "empty" hydraulic cage is being loaded with empty tubs; as soon as the cage settles on the "fallers," hydraulic rams push the empty tubs into the cage, at the same time pushing the full tubs out of the winding cage into the hydraulic cage. By this means all the four decks are loaded and unloaded, surface and underground, simultaneously. The full tubs gravitate from the hydraulic cages to the creepers and are then raised to the tippler height. The empty tubs, after leaving the tipplers, return by means of creeper and suitable gradient to the pit mouth. Each creeper is worked by a 5 horse-power electric motor running at 570 revolutions per minute. The power house is placed about midway between the two winding-engine houses. In the electric light plant there are two sets of double-acting engines, cylinders having 12 inches diameter, and a 16-inch stroke, at a steam pressure of 120 lbs. per square inch. The generating plant for the lighting consists of two dynamos of 350 ampères and 110 volts capacity, and one dynamo of 150 ampères and 250 volts capacity. For the power the room contains four three-phase alternators, with switchboard. Two have a capacity of 90 kilowatts at 500 volts. In the No. 3 Parsons turbo-alternator the capacity is 250 kilowatts at 500 volts. In the No. 4 Parsons turbo-alternator the capacity is 450 kilowatts at 500 volts. There are three coal-washers, the Baum, in course of erection, the Lührig, and the Humboldt—capacity, 250, 60, and 100 tons per hour respectively. All the water from the washer is conducted to settling tanks. After the water has settled for some time, it is then drawn off perfectly clean and used over again; the settlings are then cleaned from the tanks by bucket elevators into waggons, and conveyed to the boiler fires for fuel. There are 180 coke ovens of the retort beehive type, and ten patent ovens, 30 feet long and 6 feet wide. All the coal is raised from the Barnsley seam, which has attained a thickness of 10 feet. The workings are on the pure longwall method, and all roads are laid out with a view—as on the surface—to facilitate the quick handling and despatch of coal. The above particulars are abridged from a paper contributed by Mr. Walter Wilkinson to the South Yorkshire Association of Mining Students (March 1906). A specially prepared reprint of this paper was handed to each of the visitors in the train.

VISIT TO TEES-SIDE.

In connection with the visit to Tees-side an influential local committee was formed, the executive of which comprised Sir Hugh Bell, Bart., President-Elect, Chairman; Mr. William Whitwell, Past-President; Mr. Arthur Cooper, Mr. James Riley, Vice-President, Mr. J. E. Stead, F.R.S.; Mr. Tom Westgarth, Mr. Illtyd Williams, and Mr. John H. Amos, Hon. Secretary. The Tees Conservancy Commissioners presented to each visitor a handsomely bound copy of a profusely illustrated work on the Ports of the River Tees, compiled for the occasion by Mr. Amos, Secretary to the Commissioners. The visitors also received an artistic detailed programme of the visit to Tees-side, covering twenty-eight pages. The party reached Middlesbrough at 9.40 A.M. on Tuesday, July 31, where they were welcomed by the reception committee in the large room of the Cleveland Club, and subsequently separated into sections for visiting the various works to which they had been invited, viz., Messrs. Bell Brothers, Ltd., Clarence Works; Messrs. Bolckow, Vaughan and Company, Ltd., Cleveland Iron and Steel Works; the Cargo Fleet Iron Company, Ltd.; Messrs. Dorman, Long and Company, Ltd., Britannia Works and Clarence Steel Works; Messrs. Richardsons, Westgarth and Company, Ltd., and the North-Eastern Steel Company, Ltd. After inspecting the works, the party was entertained at luncheon in the Town Hall. Sir Hugh Bell, Bart., occupied the chair, and was supported by Captain R. W. Hunt, Dr. R. W. Raymond, Sir Thomas Wrightson, Bart., Sir S. A. Sadler, and prominent representatives of the Tees-side industries. The menu was tastefully arranged, and contained photographs of places of interest in the district. An excellent band was in attendance. After the usual loyal toasts had been duly honoured, the Chairman proposed "The American Guests," whom he warmly welcomed to Tees-side. The toast was acknowledged by Captain Hunt, after which Dr. Raymond proposed "The Trade and Commerce of Tees-side," which was responded to by Sir Thomas Wrightson, Bart., and Sir Samuel Sadler. Sir Hugh Gilzean Reid proposed the health of the Chairman, which was suitably acknowledged, after which the company separated, and soon afterwards left Middlesbrough for Durham.

BELL BROTHERS, LTD., CLARENCE WORKS.

Sir Hugh Bell, Bart. (chairman), Mr. Greville T. Jones (manager), and Mr. W. L. Johnson (director), showed the American visitors over Clarence Works.

At the Clarence Works, situated on the north bank of the river Tees, belonging to Messrs. Bell Brothers, Ltd., there are twelve blast-furnaces and a steel works leased to Messrs. Dorman, Long.and Company, Ltd. There are twelve furnaces built and eight in operation, producing Cleveland pig iron at the rate of 350,000 tons per annum. A substantial quantity of the output goes to the steel works, while the balance, which is mostly foundry iron, is sent to local works, Scotland, various parts of England, most of the countries on the Continent of Europe, India, Australia, Canada, &c. &c. Indeed there are very few civilised countries to which the foundry iron of the "Clarence" brand has not found its way. In the past, in times of exceptional demand, large quantities have even gone to the United States, but since the production of a somewhat similar class of iron in the Southern States has been developed that would only very occasionally be now possible even if the tariff were abolished. The ironstone for the furnaces comes from mines in Cleveland owned by Messrs. Bell Brothers, Ltd., the coke partly from their collieries in Durham and partly from the by-product ovens erected at Clarence in co-operation with a German firm, where about 2800 tons per week are now produced, and the limestone from their quarry in Weardale, County Durham. The total number of men employed under the Company is about 5500.

BOLCKOW, VAUGHAN AND COMPANY, LTD., CLEVELAND IRON AND STEEL WORKS.

Messrs. Arthur W. Richards (works manager), T. Davies, D. Wilson, G. Bellwood, T. Prosser, W. Anderson, A. Stainsby, J. Webb, and C. Jones conducted the party over the works.

The works of Messrs. Bolckow, Vaughan and Company, Ltd., are situated on the south side of the river Tees, about three miles from Middlesbrough, and comprise blast-furnaces, steel works, and ironstone mines.

The blast-furnaces are in six groups—twenty-five furnaces in all, of which twenty are in operation, with the necessary hot-blast stoves, calcining kilns, blowing-engines, boilers, &c. Three of the furnaces are mechanically charged, the remainder being charged by manual labour. Several grades of iron are produced, viz. Cleveland, hæmatite, spiegeleisen, and ferro-manganese, the total output of all grades of iron being 940,000 tons per annum. The greater portion of the Cleveland ironstone is brought from the Company's own mines at Eston, a distance of two and a half miles, by their private railway to the calcining kilns, the remainder being brought from mines near Saltburn. The total output of ironstone from the Company's mines is 2¾ million tons per annum. The hæmatite ore is brought by vessels from Spanish and other foreign ports and discharged at the Company's own wharf, which has a river frontage of about 1500 feet. The slag from the furnaces is taken away in ladles and tipped in a molten state for filling up the foreshore of the river Tees in front of the works.

At the steel works, the manufacture of steel is carried out by the acid Bessemer, basic Bessemer, and acid and basic open-hearth processes. There are two metal mixers each of 150 tons capacity; ten converters each with a capacity of from 8 to 15 tons; eight open-hearth furnaces each with a capacity of from 20 to 60 tons; one 48-inch blooming-mill for rails, &c.; one 60-inch slabbing-mill for plates; one rail-mill for ordinary rails from 40 to 100 lbs. per yard; one mill for street tram rails up to 120 lbs. per yard if required by 60 feet long, also steel sleepers, joists, and merchant sections; one small mill for all sections of fishplates, light rails, &c., up to 40 lbs. per yard; two plate-mills, one capable of turning out plates from ⅜ inch to 3 inches thick by 108 inches wide, and the other mill from ⅛ inch to 1 inch thick by 84 inches wide; the rail finishing department contains all the necessary machines for preparing the rails, &c., for shipment. The greater part of the auxiliary machines in the steel and iron works is electrically driven, the current being three-phase alternating and supplied from the Company's own power station. The total output of finished steel is 234,000 tons per annum. The Company own extensive collieries in the Durham coalfield about 30 miles from Middlesbrough, the output from which is about 1¾ million tons per annum. The total number of men employed under the Company is about 12,000.

Cargo Fleet Iron Company, Ltd., Cargo Fleet Works.

Mr. C. J. Bagley (managing director), and Mr. Benjamin Talbot (director), conducted the party over the works. A descriptive pamphlet was prepared for the use of the visitors.

This Company owns the Liverton Mines, the Mickleton Limestone Quarries, and the Cargo Fleet Iron Works, all of which have been in existence for a great many years. The whole of the combination has recently been remodelled, and large steel works and rolling-mills have been erected. In order to bring the old plant into line with the new extensions, considerable alterations had to be made in the lay-out of all the sidings, in order to deal efficiently with the increased and altered form of output, and the greater diversity of raw material required for such output.

The blast-furnace plant consists of two furnaces, 90 feet high, 11 feet hearth, and 21 feet bosh, the blast being heated by twelve Cowper stoves. This plant has been remodelled from the older plant, which originally consisted of five smaller furnaces. Each of the present furnaces is capable of producing some 1200 to 1400 tons of pig iron per week, all of which is taken in a molten state to the Talbot plant for conversion into steel. Seven gas-blowing engines of the Cockerill type, built by Messrs. Richardsons, Westgarth and Co., Ltd., Middlesbrough, are installed. The engines are all single Otto cycle engines, delivering 14,000 cubic feet of free air at 10 to 12 lbs. per square inch. They are, however, capable of delivering against a pressure of 17 to 18 lbs. per square inch when necessary. The gas cylinders are 51½ inches diameter, blowing cylinders 59 inches diameter by 55 inches stroke, and run at 70 to 80 revolutions per minute. Each of these engines can be separately connected to either furnace, three being required for each, and one remains as a stand-by. The engines are spanned by a 3-motor 20-ton crane. The cooling water for the pistons and cylinder jackets is supplied from a tank to the engines, and is then pumped by two electrically driven turbine pumps on to a Morrison cooling tower, and then pumped to the tank to be used over again. The gas-washing plant consists of three Theisen gas washers, two of which are capable of dealing with the gas from both furnaces. This amounts to 1800 cubic metres per minute. Each washer is driven at a speed of 310 revolutions per minute by a 150 brake horse-power Brown-Boveri motor. The gas enters the washer or fan at a temperature of 300° to 500° F., containing only 0·016 to 0·02 grammes of dust per cubic metre. The gas is then suitable for going to the gas-engines, and is also very much more efficient under the stoves and boilers. The quantity of water required by the washers varies from 1 to 2 litres per cubic metre of gas washed, depending upon the dust contents and the temperature of the ingoing gas.

There are six Babcock and one Nesdrum water-tube boilers for supplying steam to a 1000 horse-power turbo-generator and the necessary steam for the coke-oven plant and engines on the Brown hoists. A gantry runs along the back of the furnaces, on to which the trucks of ore, limestone, and coke are taken by an inclined electric hauling arrangement and emptied into the ore and coke bins where required, and then run on to a balance drop hoist to the works level again. A long ore and coke bin is placed behind each furnace. These are divided into the necessary number of compartments for the various kinds of raw material. The ore, &c., is automatically taken from these bins on to a weighing machine and delivered into the skip. The materials are then taken to the top of the furnace and automatically tipped into the furnace by a Brown Hoisting Co.'s skip and bell arrangement, which secures very equal distribution of stock into the furnace, and is all operated by one man from the hoist engine-house below. Each furnace is fitted with Sahlin's patent bosh, and bronze or copper tuyeres, which makes a very simple and effective cooling lay-out. A Vaughan gun is used for plugging the tap-hole, and this is done while the blast is on the furnace. Only on very rare occasions has it been found necessary to take the blast off for closing up the hole after casting. Two pyrometers of the Callendar type are fitted to each furnace, one for the blast temperature and one for the waste gases.

This furnace plant is designed for an output of 1400 tons per furnace per week, using Cleveland calcined ore and the necessary fluxes to produce basic pig iron suitable for the Talbot continuous process of making steel.

The coal-washing plant consists of a Humboldt washery capable of dealing with 60 tons of coal per hour. The Humboldt concentric screen separates into six different sizes, five of which are treated on the jigs, and the sixth, in lumps too large to pass any screen, go on to a breaker, and then return to the washery. The washed coal is raised by a large elevator to a trough, where, by means of a right and left hand spiral conveyor, it is delivered into two disintegrators, and the disintegrated coal passes on to a Robins belt conveyor to the coke-oven coal store.

The coke-oven plant consists of one hundred Kopper ovens, fifty at each side of the washed coal store. These are fed by two double-box coal compressors of the Baroper type, and travel under the coal store, where they receive the washed coal into a box the same size as the oven. The coal is compressed by means of stampers in a box, and the compressor, which is electrically driven, travels opposite each oven and pushes the cake of coal into the oven. After burning, the coke is ejected by a pusher and sprinkled with water on an inclined bench, and ultimately delivered into a coke car, which in turn delivers it into the coke bins for the blast-furnaces, or into stock, as may be required. The gases from the ovens pass to the by-product plant, where sulphate of ammonia and tar are recovered. The amount of gas available for power purposes, after leaving this plant, is capable of developing 3000 horse-power in gas-engines.

The electric generating station comprises one compound steam direct driven set of 350 kilowatts, one steam turbo-generator set of 750 kilowatts, and two Premier gas-engines, each directly connected to two 300 kilowatt generators. All the generators are of the Brown-Boveri make, and run in parallel on a 220 volt continuous current circuit. The works load distributed by one large switchboard, consisting of six panels, is of a very varying character, and from the description of the work it will be seen that the task of running all these various types of generators in parallel was no easy one.

The supply of ironstone for the blast-furnaces is obtained from the Company's Liverton Mines, situated on the North-Eastern Railway, near Loftus, about 20 miles from Cargo Fleet. The royalty extends over about 2500 acres, and the seam of ironstone varies in thickness from about 9 feet to a little over 6 feet. The mines have been worked for some time, but only with a small output, and it is calculated that the quantity of stone amounts to between 30 and 40 million tons. The Company's requirements for two blast-furnaces are about 7000 tons per week, and the whole of the appliances at the mines have been remodelled to enable this output to be obtained by working only one shift of eight hours daily.

The steel-smelting shop contains three 175-ton Talbot furnaces. The gas for working these furnaces is supplied by ten mechanically-stirred Talbot producers. On the furnace platform is provided an electrically-driven Wellman charging machine. Two 40-ton hot metal cranes are provided on the charging side, and a 75-ton steel casting crane on the casting side of the furnace plant. One 150-ton gas-fired mixer is installed, together with the necessary crushing and grinding plants for manganese, pig, and dolomite, &c. The Talbot furnaces are operated by gas-reversing valves of the water-sealed type, and specially designed air valves and dampers, each

Talbot furnace having a separate chimney stack. These furnaces have been built by Messrs. Richardsons, Westgarth and Company, Ltd., Middlesbrough. The producers are built in a row behind the steel smelting shop, and the coal is elevated from the railway trucks to the bunker above by a Royce crab elevator. The coal from the bunker is mechanically fed and distributed into the producer. The poking gear is driven by two small steam-engines. The blast for blowing these producers is delivered by four Samuelson blowers driven by steam. The exhaust steam from these engines is utilised for providing the necessary steam to be driven along with air to the producers. The gas produced by these producers amounts to 150,000 cubic feet per ton of coal gasified. The operation of this plant is as follows :—The pig iron is run from the blast-furnaces into hot metal ladles of 20 to 25 tons capacity, and these ladles are conveyed on carriages to the melting shop, where the metal is poured into the metal mixer. Here a portion of the sulphur and silicon is eliminated, and the metal from the mixer is poured into a 20-ton ladle, carried by a 40-ton crane, and transferred in a molten state to the steel furnaces. In starting up the steel furnaces at the beginning of the week 50 to 70 tons of steel scrap is charged by an electric charging machine in the ordinary way. When this is melted, along with the necessary reagents, metal from the mixer is added, and the charge worked until the furnace contains 175 tons of steel of the desired quality. Fifty tons of this steel are poured into a ladle and carried by a 75-ton crane, and cast into ingot moulds of 3 to 5 tons capacity, which are carried on cars. The charge in the furnace is now 125 tons. This is over-oxidised by the addition of reagents, and another two ladles containing approximately 25 tons of iron are added, when a violent reaction takes place, and in a very short time the bath is ready for another 50 tons to be drawn off. Thus it will be seen that the process is a continuous one. The ingots now cooling on the casting cars in the moulds are taken by a locomotive to an ingot stripper. The yield of steel from every 100 tons of pig put in is 104 to 106 tons of steel ingots, the gain being obtained from iron in the reagents used. The yield of steel from ordinary open-hearth basic furnaces amounts from 92 to 94 tons for every 100 tons of pig and scrap charged. The slag from the Talbot steel furnaces contains from 15 to 19 per cent. of phosphoric anhydride as compared with 10·5 to 12·5 in an ordinary open-hearth basic plant. A basic slag works is being put down for treating slag from the Talbot furnaces for agricultural purposes.

Two rolling-mills have been constructed, one for cogging and the other for finishing. The cogging plant consists of two gas-fired soaking pits spanned by a 15-ton crane, which takes the ingots from the casting car to the soaking pits, and after heating removes them from the soaking pit to the mechanical chair, which in turn deposits the ingot on to live roller gear, conveying material to the mill. The mill itself is 40 inches centre by 8 feet 6 inches rolls, driven by three-cylinder compound condensing engines, 45 inches diameter, 52 inches stroke. All cylinders are the same size, there being one high-pressure and two low. These engines were built by Messrs. Richardsons, Westgarth and Company, Ltd., Middlesbrough, and are provided with the Rottman valve gear, which enables them to be operated either as compound engines or as high-pressure engines. The ingots, after being cogged down to the required size, are conveyed by the live roller gear, all of which is electrically driven, to the hydraulic bloom shears, where they are cut up to the required lengths and transferred by a Collins charger into the two gas-fired re-heating furnaces to be re-heated preparatory to finishing. The finishing-mill consists of four stands of rolls driven direct by an engine similar to the cogging-mill engine. The re-heated bloom is brought from the re-heating furnaces and deposited on to a live roller table, which carries it forward on to the first pair of rolls. The mill is provided with two travelling tables, one on each side of the rolls. After leaving the finishing rolls the piece is carried forward by an extended roller rack to the hot saw or shears as may be required. The finishing-mill is spanned by a 60-ton crane, so arranged that for roll changing the housings and rolls are lifted bodily out, and the new set of rolls put in. Beyond the finishing-mill is a hot bank, 100 feet by 52 feet. After the material has crossed the hot bank it is conveyed by live roller gear through straightening presses to the shears.

The boiler plant provided for supplying steam to these mills consists of ten Nesdrum and two Lancashire boilers, the boilers being provided with coal-fired grates, and also gas burners for utilising the gas left over from the blast-furnaces, which it is anticipated will produce one-third of the steam required. All the boilers are equipped with induced draught and provided with economisers. The condensing plant put down is of the Weiss type, capable of dealing with the steam from three mill engines of the size already indicated, and the necessary hydraulic, circulating, and boiler feed pumps. The pump house is equipped with electrically driven circulating pumps, steam driven dry-air pumps, condenser-water pumps, steam-driven hydraulic pumps, and boiler feed pumps.

DORMAN, LONG AND COMPANY, LTD., BRITANNIA WORKS.

Mr. Alfred M. Mosscrop (general manager) conducted the party over the works, and presented each visitor with a handsomely bound volume containing a complete illustrated account of the productions of the Company.

The Britannia Works comprise steel furnaces, rolling-mills, and constructional and bridge shops. The steel is made by the basic open-hearth process, and is rolled into sections of all descriptions for engineering, shipbuilding, general constructional work, and allied trades. The sections rolled include beams 24 inches by 7½ inches to 3 inches by 3 inches, channels 15 inches by 4 inches to 4 inches by 3 inches, angles 8 inches by 8 inches to 3 inches by 3 inches, bulb angles 12 inches by 4 inches to 5½ inches by 3 inches, also zeds, tees, and other sections. The output of the constructional shop is 3500 tons of finished work per month. These shops are the largest and best equipped in Great Britain.

DORMAN, LONG AND COMPANY, LTD., CLARENCE STEEL WORKS.

At the Clarence Steel Works of Messrs Dorman, Long and Company, Ltd., Port Clarence, the visitors were received by Mr. A. H. Cooper (general manager), and Mr. A. Dorman (assistant general manager).

The melting shop at these works contains four 50-ton and four 45-ton Siemens steel furnaces, which are supplied with molten iron from a gas-heated mixer having a capacity of 200 tons. The steel manufactured is mostly for special purposes, with carbon ranging from 0·08 per cent. to 1·5 per cent., a few of the specialities being—soft steel for high conductivity wire and locomotive tubes, and hard steel for saws, picks, wire ropes, files, edge tools, &c. The rolling-mills are three-high, consisting of three trains of rolls, cogging, roughing, and finishing, the diameter of each of these mills being 34 inches. The product of the mills is principally billets and slabs for the purposes above described.

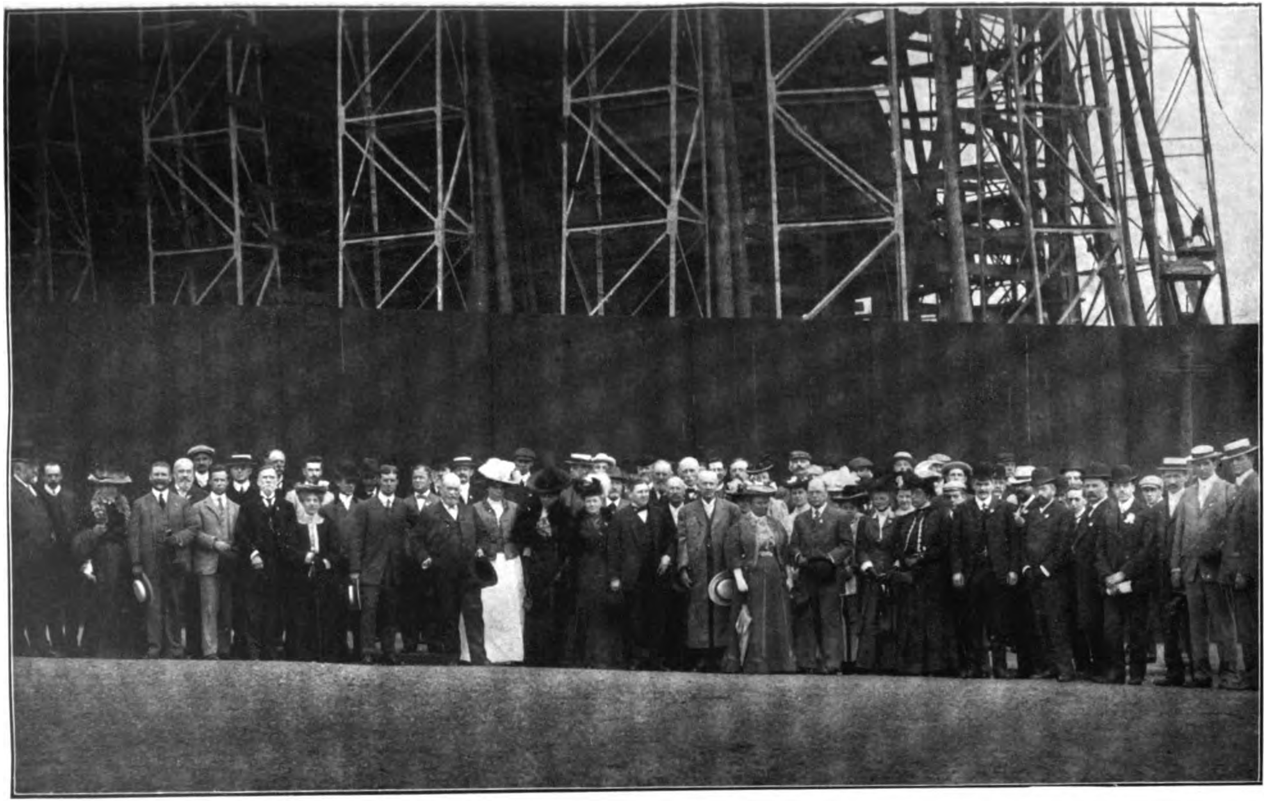
RICHARDSONS, WESTGARTH AND COMPANY, LTD.

The visitors were conducted over the works by Mr. Tom Westgarth (managing director), Mr. Jackson (works manager), and his assistant (Mr. Key).

Richardsons, Westgarth and Company, Ltd., are marine and general engineers, boilermakers, &c.; they also build steel-works plant, gas-engines of large size, tilting furnaces, &c. The Talbot furnaces, the cogging and finishing mills with their 18,000 indicated horse-power engines, and the complete installation of gas-driven blowing-engines at the Cargo Fleet Company's Works, were built by Richardsons, Westgarth and Company, Ltd. A great variety of work was seen in progress, including marine-engines, quarter-crank blowing-engines and gas-engines, comprising one of 1000 indicated horse-power for dynamo work to use blast-furnace gas. This engine has two double-acting tandem cylinders 29½-inch diameter by 35½-inch stroke, to run 120 revolutions. Another engine of 900 indicated horse-power for driving a ventilating fan for the Powell-Duffryn Coal Company, South Wales, to use waste gases from patent coke ovens, has two single-acting cylinders 35½-inch diameter by 39½-inch stroke. Another gas-engine, under construction, is for rolling-mill work, and will yield 1500 horse-power, with four double-acting cylinders on two cranks, the size of cylinders being 25½-inch diameter by 31½-inch stroke, to run 120 revolutions, the shaft between the two cranks to carry a 50-ton flywheel. In the boiler shops were seen marine boilers for 180 lbs. working pressure, about 16 feet diameter, each weighing about 50 tons; also various other work, including a 200-ton Talbot patent tilting furnace for Messrs. Palmer, of Jarrow, and others for the South Durham Steel and Iron Company.

THE NORTH-EASTERN STEEL COMPANY, LTD.

The visitors were conducted over the works by Mr. Arthur Cooper (managing director), Mr. F. W. Cooper, Mr. P. S. J. Cooper, Mr. Calderwood, Mr. Marston, and Mr. Ridsdale.



VISIT TO WALLSEND-UPON-TYNE.

The North-Eastern Steel Company's Works were built in 1881–83 for the express purpose of making steel from phosphoric pig by the basic process. The Acklam blast-furnaces adjoining, four in number, were acquired about ten years ago, since which time the whole plant has been remodelled. There are three blast-furnaces in blast, making basic iron for use at the steel works, and they produce from 1400 to 1600 tons each per week. Adjoining the blast-furnaces is a battery of fifty coke ovens of the Semet-Solvay type, complete with recovery plant. The iron is brought in the molten state from the blast-furnaces to the mixers, of which there are two of 160 tons capacity each. There are four Bessemer converters, each of 12 tons capacity. The output of steel from the converters is about 4000 tons per week. The mills were originally laid out to roll rails and semi-finished material. During the last ten years there has been laid down a new mill for rolling tram rails and girders, together with very extensive hot banks and finishing plant. In connection with the steel works there is also a basic slag works for the manufacture of basic slag, about 1200 tons being made per week.

VISIT TO FOUNTAINS ABBEY.

On the morning of Tuesday, July 31, the ladies of the party left York at 8.43 A.M. by special train for Ripon, which was reached at 9.56. In connection with this visit a ladies' committee had been formed consisting of: Lady Bell, Lady Ropner, Lady Sadler, Lady Wrightson, Mrs. John H. Amos, Mrs. Arthur Cooper, Mrs. A. J. Dorman, Mrs. John Hedley, Mrs. James Riley, Mrs. J. E. Stead, Mrs. T. Westgarth, Mrs. Illtyd Williams, Miss Hedley, Miss Gilzean Reid, and Miss Whitwell.

The party was met at Ripon by Lady Bell and other members of the committee and conveyed by the North-Eastern Railway Company's motor cars from Ripon Station to Studley Royal, a visit being paid *en route* to the town hall, Ripon, where the corporation regalia and plate were inspected. On arrival at Studley Royal the party proceeded on foot through the park, to which access was obtained through the Canal Gate entrance. During the earlier part of the visit rain fell, but later on the weather cleared up, and in the afternoon the sun shone brightly, which enabled the party to view the historic ruins of Fountains Abbey under very favourable conditions. Luncheon was served in the cloisters of the Abbey at 12.15 P.M., by special permission of the Marquess of Ripon. Lady Bell took the chair, and on the conclusion of the repast Mrs. Hunt proposed a vote of thanks to Lady Bell and to the ladies of the committee for their kindness in making the arrangements for the excursion. The vote of thanks was acknowledged by Lady Bell.

Studley Royal, the beautiful estate in which Fountains Abbey is situated, belongs to the Most Honourable the Marquess of Ripon, K.G., P.C. The park measures, from east to west, about one mile, and the avenue which traverses the estate is one of the most beautiful in the kingdom, the foliage being carefully cleared at various points to allow landscape views of Fountains Abbey to be obtained. The Hall itself stands on the higher ground in the north-west corner of the park, the present mansion having been built in the year 1720, on the site of an earlier mansion which was burnt down in the year 1716. Fountains Abbey was founded by a company of the Benedictine Monks of St. Mary's Abbey at York, who, being discontented with what they considered the laxity of the discipline which prevailed there, withdrew themselves from their monastery in order that they might adopt a stricter rule and more severe discipline. Thurston, Archbishop of York, granted them lands in the patrimony of St. Peter, and in 1478 the Abbot John Durnton resumed the work of construction which had been commenced in the thirteenth century by John de Ebor, but which, owing to the depredations committed by the Scots, had been from time to time postponed. The beautiful tower of Fountains Abbey was, however, built by Abbot Huby in 1494. The nave is 199 feet in length and 66 feet in width, having the usual disproportion characteristic of Cistercian churches. The Abbey was built in the pointed Norman style. One of the features of Fountains Abbey is the cellarium, in which luncheon was served. The original purpose of this building is not known, although it is believed that portions of it were used by the cellarer for the stores in daily demand. It consists of two long vaulted rooms running southward parallel with each other and at right angles with the nave. Each division is 300 feet in length and 21 feet in width, and a series of nineteen octagonal columns, each 5 feet 2 inches in circumference, support the roof midway. The cellarium is not generally open to the public. On leaving Fountains Abbey, the party journeyed to Ripon, where a visit was paid to the Cathedral. The Honourable Mrs. Freemantle and the Rev. Canon MacColl, Canon in residence, received the visitors in the absence of the Dean of Ripon, the Very Rev. and Hon. W. H. Freemantle, D.D., who, being indisposed, was unable to attend. Canon MacColl explained the architectural details of the Cathedral, which is one of the five widest cathedrals in the country, the width of the nave being 87 feet. Ripon Cathedral contains what is believed to be the oldest complete chamber attached to any English cathedral, which dates back to Saxon times. An illustrated booklet containing views of the Cathedral, and an illustrated volume giving the history of Studley Royal and Fountains Abbey, were distributed amongst those taking part in this excursion. At a quarter to three the party left Ripon for Durham, which was reached at half-past four.

VISIT TO DURHAM.

At Durham the party of members who had in the earlier part of the day visited Middlesbrough was met by the party who had visited Fountains Abbey. Brakes were provided at the station, and the visitors were driven through the town to the Cathedral enclosure, and thence to the Castle. Tea was provided in the hall of the Castle, after which the Rev. H. Gee, D.D., Master of the University College, conducted the party to the Cathedral, where they were met by the Very Rev. Dr. Kitchin, Dean of Durham, and Warden of the University, who accompanied them around the Cathedral, and eloquently explained the architectural and historical features. Durham Cathedral is beautifully situated on an eminence overlooking the city. It is one of the largest cathedrals in the country, the total external length of the nave being 502 feet, and the breadth 81 feet. The central tower, which is 218 feet, is the loftiest in England, with the exception of that of Lincoln. Portions of the original Saxon church are found in the crypt. The foundations of the present Cathedral were laid by Bishop Carileph, in 1093. The Cathedral is usually regarded as the leading type of the Norman style. The See of Durham is extremely wealthy, and the prince bishops for many years exercised almost royal rights over the diocese. It originally contained the shrine of St. Cuthbert, which was a noted place of pilgrimage until the Reformation. On the conclusion of the visit the party were again driven in brakes to the station, whence they were taken by special train to Newcastle-upon-Tyne.

VISIT TO NEWCASTLE.

The party reached Newcastle on the evening of Tuesday, July 31, and were at once distributed among the various hotels in which accommodation had been secured. On the morning of Wednesday, August 1, they were received at the Wood Memorial Hall, the headquarters of the North of England Institute of Mining and Mechanical Engineers, by the Right Hon. the Lord Mayor of Newcastle (Alderman Sir J. Baxter Ellis), who was accompanied by the Sheriff (Councillor Johnstone Wallace) and Mr. T. W. Benson, President of the North of England Institute of Mining and Mechanical Engineers. Mr. M. Walton Brown, Secretary of the North of England Institute of Mining Engineers, acted as hon. secretary of the reception committee, and the excursions arranged on this occasion were taken part in conjointly by the members of that Institute, together with those of the American Institute of Mining Engineers, and of the Iron and Steel Institute. On the morning of August 1, the following alternative excursions were arranged: A trip on the river Tyne, visiting the coal staithes of the North-Eastern Railway Company at Dunston, and proceeding thence to the Wallsend and Walker Works of Messrs. Swan, Hunter and Wigham Richardson, Limited, and the works of Sir John Jackson, Limited, contractors for the reconstruction of a portion of the North Pier. Excursion No. 2 included visits to the Hylton, Wearmouth, Dawdon, and Horden Collieries, and excursion No. 3 consisted of a drive from Lucker to Bamburgh Castle, and from thence to Alnwick Castle. On the latter excursion, a party of about 150 proceeded by train from the Central Railway Station, Newcastle-on-Tyne, to Lucker, where the party alighted and were driven to Bamburgh Castle, where they were received by a representative of the Right Hon. Lord Armstrong, who was unfortunately prevented from being present, but who sent a warm message of welcome to the visitors. Luncheon was served in the Great Hall of the Castle at 1.30 P.M., and the speech welcoming the guests was responded to by Dr. Raymond. The party then proceeded to view the Castle, after which they were again driven *via* Seahouses and Embleton to Alnwick Castle, the seat of His Grace the Duke of Northumberland. The time at the disposal of the visitors being exceedingly short, this visit had to be somewhat curtailed, and after tea had been served the party left Alnwick by special train at 6 P.M.

In the evening a conversazione was held by invitation of the North of England Institute of Mining and Mechanical Engineers, in the Laing Art Gallery, New Bridge Street. The company were received by Mr. T. W. Benson, the President, assisted by members of the Council. There was a concert in the Upper Hall by Mr. H. G. Amers' orchestra, and the special loan collection of pictures by Mr. T. M. Richardson, senior, and members of his family, proved most attractive. An interesting feature was a performance in the supper-room by Messrs. R. M. Mowatt and T. Clough on the Northumberland pipes. An erudite note on the antiquity of these instruments was prepared for the occasion by Mr. R. Oliver Heslop, M.A., F.S.A. On Thursday, August 2, two alternative excursions were arranged, one being to the Chesters and Borcovicus Camp, and the other to the Elswick Works of Sir W. G. Armstrong, Whitworth and Company, Ltd.

EXCURSION ON THE TYNE.

A large party of visitors, including ladies, left the Fish Quay, Newcastle, on the morning of Wednesday, August 1, on the steamer *J. C. Stevenson*, which had been kindly lent by the Tyne Improvement Commissioners, and proceeded up the river under the guidance of Mr. Joseph Fairless to visit the Dunston coal-shipping staithes of the North-Eastern Railway Company, where they were received on arrival by Mr. Charles A. Harrison.

Coal shipments in the North of England are carried out almost without exception from elevated jetties or staithes, either run out at right angles to the river, with one or more end-tipping spouts, or parallel to the river, with a series of side-tipping spouts, such as are in existence at the staithes belonging to the North-Eastern Railway Company at Dunston-upon-Tyne. The existing staithe is 1709 feet long, being run out from the land into the river and parallel to it by a curve of 396 feet radius. There are three berths, about 260 feet apart, each berth containing two sets of four, five, or six spouts, according to the height of the staithe, the spouts being spaced 87½ feet apart from centre to centre. The top is laid with three lines of rails on an up gradient of one in ninety, with the necessary points and cross-over roads. The two inside roads are the full ones, up which the coal-trucks are pushed by locomotives to the staithe-head; the coal trucks are then dropped back by gravitation through the points and down the outside or empty road, tipped down the shoot in batches of about a dozen at a time, and the empty trucks return to the standage. Under ordinary conditions, about forty trucks, each carrying 10½ tons, can be teemed down one spout in an hour, giving an average daily rate, including stoppages, of 4000 tons per spout-head.

The new staithes, consisting of a series of frames or trestles spaced 17½ feet apart, and braced together by 12 inches by 6 inches walings and braces, are built upon rows of 13 inches by 13 inches piles, also spaced 17½ feet apart. The superstructure consists of a double row of 13 inches by 14 inches way-beams, placed one above the other, carrying a 3 inches caulked deck, and a 14 inches by 6½ inches rail-beam under each running rail. Opposite the spouts, where the points and crossings occur, there is a solid 6½ inches deck, instead of the rail-beam. The permanent way, as on the standage lines, is of the Company's 90 lbs. bull-headed type, with chairs, and consists of two lines of way, broadening out to three at the first set of spouts, and increasing to four at the top spouts, and, at each berth, there is a nest of crossings connecting the full lines with the empty road over the shoots, which are similar in number and position to those already described on the existing staithes. The insides of the spouts are plated with ½-inch steel-sheeting.

The party on leaving the staithes proceeded down the river beneath the bridges until they reached the Wallsend and Walker Works of Messrs. Swan, Hunter and Wigham Richardson, Ltd., where they were received by Mr. C. S. Swan and Mr. John Tweedy.

Swan, Hunter and Wigham Richardson, Ltd., Wallsend and Walker.

The works are situated at Wallsend and Walker, and occupy some 78 acres of land with a river-frontage of about 4200 feet. There are sixteen slips for building vessels, the longest being 900 feet in length. There is also a yard for building large floating docks. The engineering department includes modern machine, fitting, and erecting shops, and also boiler-works. The dry-dock department contains two pontoon floating docks to lift vessels up to 350 feet in length, and a dry dock 550 feet long and 76 feet wide at the entrance. Besides the usual equipment of heavy machinery in the shipyards, there is a recent installation of electric power for driving machinery and lighting the works, and also of extensive hydraulic and pneumatic plant. The immense glass-roofed sheds covering four of the berths constitute a noticeable feature of the works. The largest of these sheds is 740 feet long, with a clear inside width of 100 feet and a height of 144 feet. All the building sheds are fully equipped with overhead electric cranes. Under one of the sheds at the time of the visit was the 29-knot quadruple screw steam-turbine Cunard liner *Mauretania*, one of the two great mail steamers ordered by the Cunard Company, under their contract with the British Government, and designed to be the fastest vessels in the Atlantic trade, and by far the largest in the world. The dimensions of the *Mauretania* are as follows: Length, 785 feet; beam, 88 feet; depth, 60 feet 6 inches; gross tonnage, 33,200 tons; maximum draught, 37 feet; and displacement at this draught, 43,000 tons. It is 78 feet 6 inches longer than the fastest of existing ships, the *Kaiser Wilhelm II.*, and 80 feet longer than the *Great Eastern*, the greatest of preceding vessels.

The Tyne Harbour: North Pier.

Luncheon was served on board, and the steamer proceeded to the mouth of the river, where the party visited the works of Sir John Jackson, Ltd., contractors for the reconstruction of a portion of the north pier. The visitors were received by Mr. Ivan C. Barling.

The exposed situation of the entrance to the river Tyne, and the stormy character of the North Sea, as well as the nature of the river bed, rendered access to the harbour a matter of considerable danger in anything like bad weather. The ugly reefs of rocks that flanked the river-mouth, and the heavy seas running on the shallow bar, were the dread of mariners. It was to overcome these difficulties that fifty-two years ago the extensive masonry-works of the north and south piers were commenced. The south pier has stood, but about eight years ago a violent gale caused the sea to make a breach in the north pier; and it was extended by subsequent storms, until the opening was about 300 feet wide. The new structure is to form a continuation of the original straight part of the pier, and will be 1500 feet in length, so that the breakwater, when finished, will be straight from end to end, and of a total length of about half a mile. The outer end of the old pier forms a shelter for the new work; but, after the latter is finished, this part of the original construction will be removed, otherwise it might become a source of danger to the new structure. Profiting by experience, the foundations will be carried down to the hard shale, thus doing away with the rubble-mound which was formerly used. Above low-water level the section is the same as in the original structure. The structure is of concrete blocks, bonded together, the largest weighing from 30 to 40 tons, no mass-work being used below high-water level. The blocks are made at the works on shore, close to the end of the pier, where the necessary plant has been installed, comprising a rotating concrete mixer, a number of moulds for forming the blocks, and other necessary appliances. The outside surfaces of the blocks, exposed to the sea, are faced with granite-blockers, built into the mould, and the concrete is then run in, so that the whole forms a monolithic mass when set. A half-round recess is formed on each side of the block, and when it is adjusted against a corresponding recess in an adjoining block, on the blocks being erected in position, a circular vertical hole is formed. This hole is filled, when the blocks are set, with a bolster of concrete, which thus locks the blocks together, so that they can have no motion relatively to each other. Above low-water level, the blocks are built with mortar-beds, and the joints are grouted. The bottom, which has to take the foundations, is very carefully levelled, so that the masonry may rest solid and square on its seating. A grab works ahead and removes all material that it can reach, and the hand-work is done from a diving-bell, suspended from one of the overhead travellers. The bell, 12 feet long, 9 feet wide, and 6 feet high, allows four men to work in it at once. The bed having been prepared, the blocks are lowered by the goliath cranes, and are set by divers. The new work, estimated to have a weight of about 250,000 tons, is being carried out by the Tyne Improvement Commissioners.

The party returned by train from Tynemouth Station to Newcastle-upon-Tyne.

EXCURSION TO HYLTON, WEARMOUTH, DAWDON, AND HORDEN COLLIERIES

A party numbering nearly two hundred left the Central Railway Station, Newcastle-on-Tyne, under the guidance of Mr. F. R. Simpson, at 10.37 A.M. on the morning of Wednesday, August 1, by special train to visit Hylton and Wearmouth Collieries, belonging to the Wearmouth Coal Company, Ltd., where they were received by Mr. M. W. Parrington, and after visiting the colliery and the surface works were entertained at luncheon by invitation of the Directors of the Wearmouth Coal Company, Ltd.

On the conclusion of the meal, a special train left Hylton Colliery at 1.35 for Dawdon Colliery, belonging to the Most Honourable the Marquess of Londonderry, where they were received by Mr. W. Corbett and Mr. E. S. Wood.

The party left Dawdon Colliery at 3 P.M. and proceeded to visit the Horden Colliery, where they were received by Mr. J. J. Prest, and on the conclusion of the visit a special train left Horden Colliery at 4.45, arriving at Newcastle-on-Tyne at 5.28.

At Hylton Colliery, situated on the site of the Wear Steel Works, there are three shafts: the east, west, and south pits. The east pit, 20 feet in diameter, is drawing coal from the Hutton seam, of an average thickness of 4½ feet of clean coal, at a depth of 1580 feet. The west pit, also 20 feet in diameter, is drawing coal from the Maudlin seam, 5¾ feet thick, at a depth of 1440 feet. The east and west shafts are downcast pits. The south pit, 15 feet in diameter, sunk to the Hutton seam, is the ventilating or fan-shaft. The cages in the east pit are designed and built for the adoption of a counterbalance-rope. Each cage carries eight tubs, four tubs on each deck: the intervening space, in which the men ride, adapts the cage to the double heapstead, and obviates decking. A drawbar, 2½ inches in diameter, and made of forged iron, runs through the cage from top to bottom. The cages are built in halves, and the drawbar is inserted before the two sections are bolted together. The winding-rope is attached to the top of the drawbar, and the counterbalance-rope to the bottom. By this arrangement, the extra strain occasioned by the weight of the counterbalance-rope is never applied to the cage, while the keps are never required to carry more than the weight of the cage and its load, the counterbalance-rope always being directly connected to the winding-rope by the drawbar. Ormerod detaching hooks are in use at the three pits. The output of the colliery has, up to the present time, been disposed of as unscreened gas-coal; and the jigging-screens which have been erected are not, as yet, in use. All the coal is, however, passed over the picking-belts.

Wearmouth Colliery, which was visited next, is situated on the northern bank of the river Wear, near Sunderland. Great difficulty was experienced in sinking the shafts, owing to the occurrence of a considerable thickness of quicksand near the surface; and heavy feeders of water were encountered in the fissured magnesian limestone, the maximum quantity pumped to the surface being computed at 2000 gallons per minute. The sinking of the shafts to the Hutton seam extended from 1826 to 1835, so that the difficulties to be overcome must have been very serious. The depth of each shaft to the Hutton seam is 1723 feet. The Maudlin and Hutton seams are now being worked. The Maudlin coal has been worked under the sea for a distance of about 3000 feet.

Sinking operations at Dawdon Colliery were commenced in April 1900, with the Castlereagh and Theresa shafts, each of which were designed to be 20 feet in internal diameter and 1800 feet deep, to the Hutton seam. Before reaching the coal-measures, the magnesian limestone was sunk through. Sinking was carried out through the heavily watered ground by means of pumps capable of dealing with 7000 gallons per minute, until the Theresa shaft had reached a depth of 350 feet, and the Castlereagh shaft a depth of 204 feet in magnesian limestone. The water then encountered amounted to 7050 gallons per minute, or more than could be raised by the pumps. It was then decided to continue the sinking by freezing through the remaining thickness of magnesian limestone and 92½ feet of yellow sands, rather than erect additional pumping plant. In April 1903, preparatory to freezing, 28 bore-holes were sunk around each shaft to a depth of 484 feet and 21 feet into the coal-measures. The bore-holes were completed in April 1904; and freezing was then commenced, and continued until 16th February 1906. During this period both shafts were sunk through the frozen limestone and sand into the coal-measures, and the whole of the water-bearing strata was lined with cast-iron tubbing. The total length of cast-iron tubbing in the Castlereagh shaft is 456 feet, and below this there is 108 feet of brickwork. The total length of tubbing in the Theresa shaft is 438 feet, and below this is 204 feet of brickwork. The method of sinking was well described in an address by Mr. S. Wood.

The total area of the royalties leased and owned by the Horden Collieries, Ltd., is about 19,000 acres. The Shotton and Horden Collieries have been opened out and developed during the past six years to work a portion of this property, and it is intended at a later period to open out and develop two more collieries, at Hesleden and Castle Eden respectively. At the present time, the production averages 2500 tons of coal per day. The three shafts at Horden were sunk through the magnesian limestone, before entering the coal-measures at a depth of about 1050 feet. The north and south downcast shafts are 20 feet, and the east upcast shaft is 17 feet, in finished diameter. The north shaft is sunk to the Hutton seam at a depth of 1200 feet, the total depth of the shaft being 1260 feet. Sinking was commenced on November 6, 1900, and completed on July 22, 1904. In this shaft water was met with at a depth of 198 feet, and from this point downwards to a depth of 522 feet, the shaft is secured with cast-iron tubbing. Above and below the tubbing the shaft is secured with brickwork, built solid, 14 inches thick. The sinking has passed through the Five-Quarter Main Coal, Low Main and Hutton coal-seams, all of workable section. The south shaft is sunk to a depth of 907 feet to the level of the Main coal-seam, as it is intended to work the Five-Quarter and Main coal-seams from this shaft. The east shaft is at present completed down to the level of the Hutton seam. It is intended shortly to carry it down to the Harvey seam, at a further depth of about 120 feet. During the sinking of these shafts, continuous pumping was necessary, over a period of three years, in handling from 3000 to nearly 10,000 gallons of water per minute, which were encountered in passing through the magnesian limestone and yellow sands, before the coal-measures were reached. The first portion of the screening plant, consisting of three main picking-belts and cross-belts for small and nut coal, is driven electrically. The Sirocco fan, driven electrically, will produce 350,000 cubic feet of air per minute, at a water-gauge of 4 inches. It has just been completed and set to work.

SIR W. G. ARMSTRONG, WHITWORTH AND COMPANY, LTD., ELSWICK WORKS.

A party numbering about seventy visited these works on August 2.

In the bridge-yard several large hydraulic cranes and dock gates were under manufacture. In the fitting and erecting shops, the work in hand consisted of hydraulic engines for training the 12-inch and 9·2-inch gun-mountings for several battleships and cruisers, large pumping-plant for deck purposes, and smaller machines for generating hydraulic power on board ship. In the next shop, some large cylinders and rams for the hydraulic control of dock-gates were being machined and erected. In the ordnance department the first shop is devoted to turning the various barrels for the larger guns, such as the 12-inch and 9·2-inch. Some of the latest pattern 50 calibre guns are under construction for the Government. These tubes, in some cases 40 and 50 feet long, must be finished correctly to within 0·001 inch. This work, in consequence, is of a very delicate nature, and requires long experience and highly-skilled labour.

There are a number of rifling machines for cutting out the variously-shaped grooves in the bore of the gun, which give the shot the rotation necessary to secure accuracy of aim and greater penetration. The cradles, which are required to carry the gun, so as to allow of its most efficient working and to take up the shock of the recoil, are also made here. The trunnions are formed on the cradle, not on the gun, and are so arranged that, when the gun is at rest, they can turn round a small fulcrum resting on a spring. When, however, the gun recoils the spring gives way, and a sufficiently large bearing surface comes into play. By means of this device, a gun weighing 28 tons can with ease be raised and lowered by hand. The recoil is taken up by a piston working in an hydraulic cylinder. Along this, a valve-key passing through a port in the piston is placed and so constructed that the force exerted throughout the period of recoil is practically uniform. A great saving in weight is the result. Several submerged Elswick torpedo-tubes were shown in a state nearing completion, and a very fair idea could be obtained of their working. In another gun shop, a large rifling machine was seen at work on a 12-inch gun. Farther on, under the same roof, the largest naval gun-mountings are erected. These consist of an armoured gun-house, an engine-room beneath, and an ammunition-passage, which when fitted extends to the bottom of the ship. To allow of their completion in the shop, wells 40 feet deep have been dug in the floor. The mountings carry two 12-inch guns, worked by hydraulic machinery, and weigh 420 tons. A 6-inch disappearing gun-mounting built at the Armstrong Works in Pozzuoli, Italy, was seen ready for use.

EXCURSION TO THE CHESTERS AND BORCOVICUS CAMP.

On August 2, the majority of the party left Newcastle by special train for Chollerford, and drove thence to the Chesters, the estate of Mrs. N. G. Clayton, where there is an interesting museum of Roman antiquities found in the course of excavations along the Roman Wall. The museum at the Chesters contains an admirably arranged collection of inscribed altars, sculptures, centurial stones, and smaller objects unearthed in the course of the excavations carried out by the late Mr. John Clayton at the stations on the Roman Wall which were situated on his property in the county of Northumberland, between the years 1840 and 1890. Three of the table-cases contain a very fine collection of iron weapons, tools, and implements which were found at Cilurnum or the Chesters. Nearly all of them date from the time of the Roman occupation of Northumberland. Under the guidance of Mr. J. P. Gibson of Hexham the remains of this Roman station at Cilurnum were visited. Luncheon was served at the George Inn, Chollerford, speeches being made by Dr. Robert Bell, Director of the Geological Survey of Canada, Mr. C. Catlett (Staunton, Virginia), Mr. M. Walton Brown, Mr. J. P. Gibson, and Mr. Bennett H. Brough. The party then drove for seventeen miles along the line of the Roman Wall over the Northumbrian Hills to Borcovicus, the most important Roman station along the wall. The drive was then continued to Haltwhistle, where tea was served in the Town Hall. Haltwhistle was left by special train, which contained the members who had remained in Newcastle in the morning to visit the Elswick Works, and the whole party arrived at the Windsor Hotel, Glasgow, late in the evening.

VISIT TO GLASGOW.

In connection with the visit to Glasgow an influential executive committee had been formed, consisting of Messrs. A. Lamberton, Chairman; R. T. Moore, J. G. Jenkins, W. Clark, T. B. Rogerson, W. Dixon, G. A. Mitchell, James Barrowman, J. T. Forgie, H. D. D. Barman, R. D. Munro, and A. Campion, Hon. Secretary. The programme prepared was tastefully designed, and contained views in Glasgow and on the Clyde. A map showing places of interest on the Clyde was also presented to the visitor. The covers were in each case embellished with the flags of Scotland and the United States, reproduced in colours. The occasion was made the opportunity for holding the joint summer meeting of the West of Scotland Iron and Steel Institute and the Mining Institute of Scotland. The Windsor Hotel was the head-quarters of the Institute. The party reached Glasgow on the evening of Thursday, August 2, and were met on their arrival by the Chairman and

Mr. A. Campion, Hon. Secretary, who presented the ladies of the party with bunches of white heather. On the following morning, a party of ladies and gentlemen, numbering about 500, left the Central Station at 9.35 by special train for Gourock. Among those present to meet the American visitors were the President of the West of Scotland Iron and Steel Institute, the President of the Mining Institute of Scotland, Sir John Ure Primrose, Bart., and Lady Primrose, Bailie Shaw Maxwell, Bailie Taggart, Treasurer D. M. Stevenson, and Mr. T. B. Rogerson, President-elect of the West of Scotland Iron and Steel Institute. Gourock was reached at 10.30 A.M., and the party immediately embarked on the Caledonian Steam Packet Company's steamer *Duchess of Hamilton*, which had been specially chartered for the occasion. The course taken was up Loch Long to Arrochar and thence round into Lochgoilhead, along the Cowal shores to the Kyles of Bute, and into Lochs Striven and Ridden. Luncheon and tea were served on the steamer, and music was supplied by the band of the 1st Lanarkshire Royal Engineers (Volunteers), conducted by Mr. W. H. Cole. The weather proved exceptionally fine all day, and the occasion was one which was greatly enjoyed by those present. The *Duchess of Hamilton* returned to Gourock at 4.45, and Glasgow Central Station was reached at 5.45. In the evening a reception was held at the City Chambers by the Lord Provost and Corporation of the City of Glasgow. The Lord Provost, Mr. William Bilsland, received the company, which numbered over 1000, in the Satin-wood Salon, and later on made a formal speech of welcome in the banqueting-hall. Mr. Andrew Lamberton, President of the West of Scotland Iron and Steel Institute, expressed the acknowledgment of the members of that Institute for the Lord Provost's kindness, while Captain R. W. Hunt, President of the American Institute of Mining Engineers, and Mr. R. T. Moore, President of the Mining Institute of Scotland, also thanked the Lord Provost on behalf of their respective Institutes. Sir Robert Cranston, Lord Provost of Edinburgh, then moved a formal vote of thanks, which was briefly acknowledged by the Lord Provost. A programme of music was contributed by Herrn Iff's Orchestra, by the Corporation Band, and by the Glasgow Select Choir.

VISIT TO EDINBURGH.

On the morning of Saturday, August 4, the party left Glasgow, under the guidance of Mr. John Cowan, D.L., Chairman of the Edinburgh Reception Committee, at 9.30 by special train for Edinburgh, arriving at 10.40. On reaching Edinburgh, the party were taken in brakes to the Haymarket Station, where a special train left at 11.15 for Dunfermline. The party travelled under the guidance of Dr. Ross, Chairman of the Carnegie Dunfermline Trustees, on whose invitation the visit was made. On arriving at Dunfermline, conveyances were provided to conduct the party from the station to the Carnegie Baths and Gymnasium, which were inspected with interest by those present. The party was then taken to the Abbey, where they were shown the tomb of Queen Margaret, the patron saint of

Dunfermline, which is situated at the east end of the exterior of the church. They were also shown the tomb of King Robert the Bruce, and the remains of the Frater Hall of the Monastery and the ruins of the palace in which Charles I. was born. They then proceeded through the Glen, passing the ruins of Malcolm Canmore's Tower on the summit of the Tower Hill, whence they were driven to Pittencrieff Park, where a marquee had been erected, and where luncheon was served on the invitation of the Carnegie Dunfermline Trustees, the Chairman of whom delivered a speech of welcome, to which Captain Hunt made a suitable reply. During the luncheon, the pipers of the Black Watch played Scottish national music and dances on the lawn facing the marquee, and the Carnegie Trust's band played in the park. The party were then driven to North Queensferry, a distance of six miles, where a steamer was in waiting to convey them to the Forth Bridge. They disembarked at South Queensferry, where coaches had been provided, to drive them through Dalmeny Park, by kind permission of Lord Rosebery. The party reached Edinburgh at 6 P.M., and proceeded to their headquarters at the Caledonian Station Hotel. In the evening a dinner was given in the hall of the Edinburgh Merchant Company, on the invitation of Mr. John Cowan, D.L., Chairman of the Edinburgh Reception Committee. Music, both vocal and instrumental, was provided, a selection of Scotch airs being rendered between the speeches. The hall of the Merchant Company is handsomely panelled in oak, the decorations being in mediæval style. The Company, which received its Charter in 1681, is exceedingly wealthy, and administers an estate to the value of over a million pounds. It carries on an important educational work, and controls five colleges, at which there are over 5000 pupils. It also endows a chair of political economy in Edinburgh University, and its list of benefactions includes pensions and allowances to nearly a thousand persons. The menu of the dinner was artistically produced, and contained views of Edinburgh Castle, Holyrood Palace, and the Scott Monument, together with portraits of Sir Walter Scott and Robert Burns. After the usual loyal toasts had been duly honoured, the Chairman proposed "The American Guests," which was responded to by Captain Hunt, who proposed the toast of "The City of Edinburgh," which was responded to by the Right Hon. the Lord Provost. "The Interests of Secondary and Commercial Education," which the Company have so greatly at heart, was proposed by Mr. Bennett H. Brough, and the toast of "The Chairman," proposed by Dr. R. W. Raymond, brought the proceedings to a close. A feature not in the programme was a toast proposed by Mr. Edgar C. Leonard (Albany, New York) recognising the services of the Iron and Steel Institute officials throughout the tour.

VISIT TO SOUTH WALES.

Although the Cardiff meeting of the Institution of Mechanical Engineers, to which the American visitors were cordially invited, is fully dealt with in the *Proceedings* of that Society, this report would not be complete without mention of the attractive programme that had been planned by the Chairman of the Reception Committee, Sir William Thomas Lewis, Bart. (Vice-President of the Iron and Steel Institute), and the Hon. Secretaries, Mr. T. Hurry Riches (Member of the Iron and Steel Institute), and Mr. David E. Roberts (Member of the Iron and Steel Institute). Special arrangements were made for the comfort and entertainment of the members of the American Institute of Mining Engineers who took part in the meeting, and were much appreciated by them. Briefly, the programme, that was most successfully carried out, comprised two sessions for the reading and discussion of a number of interesting papers on the mornings of Tuesday, July 31, and Wednesday, August 1, the meetings being held at the South Wales Institute of Engineers, Park Place, Cardiff. At the opening meeting on Tuesday, July 31, the Deputy Lord Mayor of Cardiff, assisted by members of the Local Reception Committee and the Presidents and Vice-Presidents of the Council of the South Wales and Monmouthshire University College, welcomed the President, Mr. Edward P. Martin (Past-President of the Iron and Steel Institute), the Council and Members of the Institution, and the American visitors. Luncheon was served in Park Hall by the kind invitation of Messrs. Guest, Keen and Nettlefolds, Ltd., after which a visit was paid to Bute Docks and to the Cardiff works of Messrs. Guest, Keen and Nettlefolds, Ltd., by a special train kindly provided by the Rhymney Company. In the evening a reception and dance was given by the Lord Mayor of Cardiff and the Lady Mayoress at the Park Hall.

On Tuesday afternoon the ladies were entertained by the Right Honourable the Countess of Plymouth at a garden party at St. Fagan's Castle, and on Wednesday afternoon a number of the ladies were entertained by Mrs. Lewis of Tynant to afternoon tea, and the rest of the ladies were entertained by the Local Committee to tea in the ancient ruins of Caerphilly Castle.

On the afternoon of Wednesday, August 1, a visit was paid to Penarth Dock, to which the visitors were conveyed by special train kindly provided by the Taff Vale Railway Company, who entertained the visitors at luncheon on their arrival. In the evening the Institution dinner was given in the Park Hall, Cardiff.

On the morning of Thursday, August 2, a number of interesting excursions were arranged, including a visit to Barry Docks, to the Powell Duffryn Steam Coal Company's Colliery at Bargoed, and to the Newport Transporter Bridge from the Alexandra Docks, Newport, while a garden party was given by the Most Honourable the Marchioness of Bute in the afternoon at Cardiff Castle. The members who visited the Barry Docks were provided with a special train by the kindness of the Barry Railway Company and were entertained at luncheon. The members who visited the Powell Duffryn Steam Coal Company's Colliery at Bargoed were entertained by the Powell Duffryn Company at luncheon, and the members who visited Newport were entertained at luncheon by the directors of the Alexandra and Newport Docks. In the evening a Welsh Concert was held at the

Park Hall, a feature of which was a selection of characteristically Welsh music rendered by the members of the Royal Welsh Choir and also by Welsh harpists.

On Friday, August 3, excursions were arranged to Chepstow and Tintern, visits being paid to Chepstow Castle and to Tintern Abbey. As an alternative an excursion was made by steamer to Ilfracombe, and the programme terminated with an illuminated fête in the Sophia Gardens, Cardiff, by invitation of the Local Reception Committee.

VISIT TO GERMANY.

At the conclusion of the tour organised by the Iron and Steel Institute, the members of the American Institute of Mining Engineers were entertained by the Society of German Ironmasters at Düsseldorf. An influential reception committee was formed, with Mr. F. Springorum, member of the Iron and Steel Institute, as president, and Dr. E. Schrödter, member of the Iron and Steel Institute, as honorary secretary. On August 13 the American visitors arrived at the headquarters in Düsseldorf. On August 14 there was a trip down the Rhine to Walsum, to see the harbours and shipping facilities of the Lower Rhine. Coming back from Walsum a stop was made at Rheinhausen, where visitors saw the Friedrich-Alfred-Hütte, the new steel plant of the Fried. Krupp Company in Essen. Dinner was served on the steamer going back to Düsseldorf. In the evening the party was entertained at a conversazione by the Mayor of Düsseldorf. On August 15, the ladies visited objects of interest in the town, while the gentlemen were invited by the following concerns to see their plants: 1. Rheinpreussen Colliery, Homber-on-the-Rhine, Pit No. IV., coal separation and washing, coking plant, by-products, gas-engines, &c. 2. (*a*) The Phœnix Company, Laar, near Ruhrort; (*b*) Rheinische Stahlwerke, Meiderich, near Ruhrort, blast-furnaces, steelworks, rolling-mills. 3. Gutehoffnungshütte, Oberhausen and Sterkrade, blast-furnaces, steelworks, rolling-mills, steel foundry, bridge-building, machine-shops, &c. In the evening a dinner at the Tonhalle, Düsseldorf, was given by the Reception Committee. On August 16 there was an excursion to Remscheid. The party proceeded by train to Vohwinkel; by suspended mono-rail electric cars through Elberfeld to Barmen; by geared electric cars to Tölleturm; by electric inter-urban service to Remscheid, where gentlemen were invited to visit the steel plant of Mr. Lindenberg (electric steel furnaces); by electric tram-cars to Thalsperre (waterworks of Remscheid, with artificial lake of about 35,000,000 cubic feet capacity, serving as a reservoir). The party then returned to Remscheid and by train to Düsseldorf *viâ* Solingen. Between Remscheid and Solingen the train crossed over the valley of the Wupper on the famous Kaiser Wilhelm Bridge, a steel structure about 350 feet high, 1650 feet long, and 230 feet span. On August 17 there was a Rhine trip. The party went by train to Coblentz; visited the champagne cellars of Deinhard and Company, and took luncheon there; they then proceeded by special steamer up the Rhine to St. Goar and back to Cologne, and by train back to Düsseldorf.

In addition to the above programme the American guests were invited by Mr. Max Meier, member of the Iron and Steel Institute, to visit the blast-furnaces, steelworks, and rolling-mills of the Differdingen Works.

There was also an excursion to Hanover (Peine steelworks, Ilsede blast-furnaces, oil-fields, potash mine, &c.) under the guidance of Dr. A. Weiskopf, member of the Iron and Steel Institute.

Detailed descriptions of the German visit have been published in *Stahl und Eisen* (vol. xxvi. p. 1090), and in the *Engineer* (vol. cii. pp. 299, 325).

REPORT ON THE INTERNATIONAL TESTING CONGRESS.

The International Congresses for the unification of methods of testing were, as has been pointed out in reports on the Zürich,* Stockholm,† and Budapest ‡ Congresses, called into existence by the late Professors Bauschinger and L. von Tetmajer. They have now been consolidated into a permanent organisation styled the International Association for the Testing of Materials. In order to show the interest taken by British metallurgists in the work, the Iron and Steel Institute votes an annual contribution to the funds, and many members of the Institute have joined the International Association.

At the Budapest Congress in 1901 it was decided that the next Congress should be held at St. Petersburg in 1904, but owing to the Russo-Japanese war, and the death of the President of the Association, Professor von Tetmajer, it was not found possible for a Congress to be held before 1906, when the cordial invitation tendered by Mr. A. Greiner to hold the Congress in Brussels was enthusiastically accepted. The Congress, which lasted from September 3 to September 9, 1906, was brilliantly successful. It was attended by 529 members and 71 ladies. The King of the Belgians was Patron of the Congress, and on September 2 received the Council of the Association in an audience lasting an hour. An influential reception committee was formed, and an executive committee, with Mr. A. Greiner as chairman and Mr. H. de Gorski as honorary secretary, ably planned an attractive programme of visits and excursions.

The meetings of the Congress were held in the Palais des Académies. At the opening meeting on September 3, Mr. F. Berger (Vienna), President of the Association, occupied the chair. The Congress was welcomed by Count de Smet de Naeyer, the Belgian Prime Minister, and by the Secretary of the Department of Railways. Professor F. Schüle (Zurich) read an address in memory of the deceased President, Ludwig von Tetmajer, who died in 1905, recalling the very important services he rendered to the progress of methods of testing. For many years Professor at Zurich, and subsequently at Vienna, he founded at Zurich an important testing laboratory in which in 1882 he carried out his first researches. In 1895 he inaugurated the International Testing Association. His researches on mild steel and on other subjects connected with structural materials assure for his name a place in the history of this branch of mechanics.

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* *Journal of the Iron and Steel Institute*, 1895, No. II. p. 310.

† *Ibid.*, 1897, No. II. p. 251.

‡ *Ibid.*, 1901, No. II. p. 321.

Baron E. de Laveleye and Mr. Camerman then read papers on the Belgian iron and cement trades.

The following is an abstract of Baron de Laveleye's memoir:

THE HISTORY OF THE BELGIAN IRON INDUSTRY.

The two principal centres of the Belgian iron industry are Liége and Charleroi. It is true that important ironworks are to be found in other districts. In Luxemburg, for instance, there are blast-furnaces; in the Centre, a blast-furnace, an important steelworks, rolling-mills, engineering works, and structural ironworks; at Mons and in Brabant, rolling-mills; at Antwerp, Brussels, Ghent, Tirlemont, and elsewhere engineering works and structural ironworks; in Flanders and in Brabant, railway carriage and wagon works, while foundries are scattered all over the kingdom. The districts of Liége and Charleroi possess thirty-two blast-furnaces out of a total of forty-two, seven of the eight Bessemer steelworks, and twenty-six of the thirty-six rolling-mills. The ancient country of Liége was the cradle of the iron industry in Belgium. This district was much more extended than the present province of Liége, and included a considerable portion of what is now the province of Namur, and extended far into Hainaut and as far as Charleroi. It is impossible to trace the origin of the iron industry of the country. Asia was certainly the birthplace, and possibly the Eburones and the Nervii, the ancestors of the Belgians, brought with them the processes which had probably long been known in their original country. History teaches that Cæsar, when he conquered the Gauls, found among the subjected tribes the art of extracting iron from its ores, which they used in the manufacture of weapons; this tends to prove that the smelting-hearth was known in Belgium in the first centuries of our era. The discovery of one of these primitive furnaces in 1870, at Lustin, near Namur, furnished an explanation of the methods then used for the manufacture of iron; the furnace still contained the raw materials in what may be termed the smelting-hearth. The furnace consisted of a simple hollow excavated in the ground, oval in shape with a rounded base, about 13 feet long, 10 feet wide, and 39 inches deep, formed in a bed of clay. A channel dug out across the clay allowed the air to penetrate to the bottom of the furnace. In this excavation metal was discovered containing 93·48 per cent. of iron, 0·37 per cent. of carbon, 4·94 per cent. of glassy slag, and 1·21 per cent. of sulphur and phosphorus, with traces of manganese. This shows the form in which the ancient Belgians obtained iron from its ores. It is probable that the Romans during their domination taught the ancient Belgians the use of the bellows and introduced other improvements in the art of smelting iron ores. During the reign of Antoninus in the second century, the iron industry extended throughout the whole district afterwards to be known as Liége, and throughout the country between the Sambre and the Meuse. The townships of this district, where about fifty years ago Belgo-Roman remains were discovered, are so numerous, that it is fair to ask whether nearly all the present villages did not, during the Roman domination, exist in the state of towns. As far as the works are concerned in the Liége district, at Chimay, near Charleroi, and at Vireux, near Namur, hundreds of these primitive forges have been discovered under the heaps of slag, their furnaces in ruins, masses of iron already forged, and others scarcely reduced at the bottom of the hearth. The heaps of slag were so numerous that in modern times they have been utilised to a considerable extent in the blast-furnaces of the district. The Couillet Company acquired one of these heaps, which contained nearly 14,000 tons of slag; the amount of iron left in this slag being from 40 to 60 per cent. Each ancient smelting operation represented a production of only a few pounds of this slag, and it can therefore easily be imagined how important the industry was. In the early centuries of our era, there is no doubt that the future Liége district, and above all the district between the Sambre and the Meuse, was the most important, from an iron-smelting point of view, in the North of Gaul, and perhaps even in the whole Roman world. The Belgo-Romans of this country had acquired remarkable skill in the art of smelting iron ores and in bending and forging the ductile metal, and handed on their art as a valuable heritage to the workmen of Liége, Charleroi, and in fact to all the Walloon workers of the present time. The impulse given to the manufacture of iron was stopped by the Germanic invasion, but in the eighth century, during the reign of Charlemagne, progress was again resumed, and, copying the Catalan hearth, the furnace was made higher than the ancient furnaces, and a more intense concentration of heat was obtained. There existed also under the Carlovingians at Liége, or in the neighbourhood, a royal manufactory of arms and armour.

It is quite natural that the manufacture of iron, which had enjoyed such extraordinary prosperity, should be rapidly developed again in a country with immense forests to supply the only fuel then used, where abundant stores of iron ore were found, with numerous water-courses which permitted, in addition to the supply of the necessary motive-power, easy and economical transport to neighbouring countries. In the twelfth century a large number of works were established all over the country for forging and working iron, and the ironworkers, united in a powerful guild, formed the most important corporation of the thirty-two guilds of the town of Liége under the name of good trade of Febures. Karsten, the metallurgist, mentions the Netherlands as the district in which the iron industry had attained at this epoch the highest degree of perfection. Up to that time only wrought iron was produced, but as the furnaces became higher, the iron manufactured, owing to prolonged contact with the charcoal, contained more carbon, and it frequently happened that, in addition to the ordinary spongy wrought iron, pig iron was produced.

By intuition the Liége workmen did not seek to avoid the accidental production of pig iron but determined to turn it to account, and it was in the Liége district that this indirect process of making pig iron was practised for the first time. This process was named, from the country of its origin, the Walloon method, and was adopted by other countries, especially by Sweden, Germany, and England, but only after the industry had been for a long time a real monopoly and the privilege of the Liége district, whose furnaces supplied the commerce of the whole world. As early as the thirteenth century cast iron was regularly produced in the Liége district.

The first blast-furnace for the production of pig iron, concerning which exact particulars exist, was erected at Lustin, near Namur, in 1340, and there is no reason to doubt that the blast-furnaces of Vennes and Grivegnée were well known before 1400. In 1468, when the troops of the Duke of Burgundy besieged Liége and sacked the town, the district, already of such industrial importance, received a terrible blow, and nearly all the forges were destroyed. In spite of this pitiless destruction, from which many works never recovered, the energetic workers caused the iron industry to spring up again from the ruins; and in Scandinavia, towards the end of the sixteenth century, the Walloons introduced the art of working metals, and had also the glory of becoming the valued helpers of Gustavus Adolphus and Oxenstierna. Guillaume Velam de Besche, a citizen of Liége, at the instigation of King Charles IX., left the episcopal principality with his four sons and founded numerous forges in Sweden; aided specially by his brother Gerard, he founded for the Swedish government the Forsmarck foundry. Side by side with these industrial colonies in the interior of the country, in the midst of forests and mines, a considerable commercial colony was constituted in the town of Gothenburg, which was chiefly composed of Dutch and Walloon Calvinists. In 1600, in 1607, in 1608 an emigration of Walloons took place, and they were distributed over the forges of Wermland. A list of the handicrafts which they exercised still exists, and comprises the various branches of the foundry, rolling and wire-drawing industries as practised at that epoch. In 1616, under Gustavus Adolphus, Louis de Geer, a Liége merchant established at Amsterdam, took 200 to 300 metallurgists, mostly Walloons, to Sweden, who turned to profit the motive-power of the water-courses of the country and the fuel of its forests. There is still preserved a list of 171 Walloons who arrived at Norrköping in 1633, and their names show their original town to have been Theux. The emigration of the Namur iron-workers attained such proportions, that by command of Philippe IV. the provincial council of Namur issued an order forbidding the inhabitants to accept employment in Sweden to introduce the art of iron working, "to the disadvantage of the Sovereign and of the State, and to the great danger of the souls of the said iron-workers." This order was issued on the 4th May 1624, and was renewed on the 11th November 1627. In a recent work, Mr. Pehr Pehrsson gives a list of 800 Walloons established in Sweden in the seventeenth century.

During the two centuries which followed the Burgundian invasion the iron industry recovered from its ruins, and the number of blast-furnaces increased so rapidly that in 1700 the Prince-Bishop of Liége issued an edict prohibiting the erection of new blast-furnaces for a period of twenty-five years. It appears also to be a fact that the cementation process for the manufacture of steel also had its origin in the Liége district. In any case, at the beginning of the seventeenth century, in 1613, permission to transform iron into steel was officially accorded to two armourers of Maestricht, a town which at that epoch belonged to the country of Liége. Karsten points out that England, which has since become the school of the metallurgy of iron, owes two great discoveries to the continent, the blast-furnace and the manufacture of steel by cementation, both of which found their origin in the Liége district. From 1738 to 1743, Liége furnished the whole of Europe with arms, and again in 1802 a cannon foundry was started, which cast a considerable number of cannons for Napoleon.

One of the principal improvements in the iron industry, the use of coke in the blast-furnace, known in England since 1619, was only introduced into Belgium at the end of the eighteenth century. In 1769 a trial was made at Juslenville, near Spa, but without success. It was not until 1821 that the first blast-furnace working regularly with coke as fuel was constructed at Seraing by the celebrated John Cockerill, an Englishman, who had been established in Liége since 1802. This blast-furnace, which remained the only one of its kind until 1830, was the forerunner of the colossal works of the Cockerill Company.

At about the same time another citizen of Liége, Michel Orban, constructed at Grivegnée the first puddling furnaces and grooved rolls, both of which had been known in England for the previous forty years. In the meantime the steam blowing-engine had been introduced. The blast-furnaces mentioned were of small dimensions. The height of the blast-furnace in 1800 was gradually increased from 3 to 5 metres, and the dimensions of the first blast-furnace of the Cockerill works, built by Mushet at Seraing, had the following dimensions :—

	Height.		Diameter.	
	Feet.	Inches.	Feet.	Inches.
Throat	15	11	5	6
Stack	31	10	12	0
Boshes	9	0	3	2 below.
Hearth	24	5	2	6 below.

The blast was supplied by a steam-engine.

In 1837 an important improvement in the manufacture of cast iron by employing the hot-blast was introduced; and this again was tried for the first time by the Cockerill Company.

Let us look backwards to see what can be discovered concerning the history of the iron industry in those parts of the provinces of Hainaut and Namur, which may be called the Charleroi district. In Hainaut the cradle of the iron industry was not Charleroi, but the districts where pure ores, which were easily smelted, were found. The first traces to be found of the manufacture of iron are in the neighbourhood of Chimay. In ancient documents an ironworks called the "Haut-Marteau" is mentioned, which existed in 1200 at Renlies, in Hainaut. In 1345 and 1384 the Count of Namur granted charters to the ironworkers and miners of Morialmé, Fraire, Florennes, and other places, conceding also a court of jurors, which proves the importance of the iron industry at this period. In 1693, in a report by Bernières, furnished to Louis XIV., the following statistics are given: "That part of the province of Hainaut which borders on the district between the Sambre and the Meuse obtains all its riches from iron mines and forges. Fourteen furnaces are employed, nine of which are in the territory of Chimay, three in a dependence of Maubeuge, and two in the territory of Avesnes. There are twenty-two forges, nineteen of which are on the territory of Chimay and Beaumont and three in the dependence of Maubeuge. All these establishments employ together about 2200 workers, including those who prepare the wood." Nearly a century later, a struggle commenced between the two great economic principles, free trade and protection. The Hainaut forges, which in 1766 were passing through a crisis, while those of the Liége district were in full prosperity, sought protection against their eastern neighbours. On the other hand, the government of the Liége district and even the Austrian Netherlands repeatedly took measures, often by force, to restrict the freedom of trade with the neighbouring countries, and several tariff wars are noted, especially in 1756 and 1765. Statistics furnish evidence of the development of the iron industry of Hainaut, and in a paper on the mines of Hainaut, Namur, Liége, and Luxemburg, published at Mons in 1816, it is stated that 118 forges drew their supply of pig iron from 50 blast-furnaces; 98 were situated in the provinces of Hainaut and Namur; and the remaining 20 belong to France. The annual consumption of each forge was 450,000 pounds of pig iron, and the blast-furnaces had a total production of 65 million pounds of pig iron. When coke was used instead of charcoal for fuel the blast-furnaces were transferred from the wooded districts to the coal regions, and the first blast-furnace burning coke was erected in Hainaut at Marcinelle, in the year 1827. Nearly thirty years later, in 1854, the first blast-furnace burning coke in the district of the Centre was started.

The most important stages of the Belgian iron industry have been noted, and only a few important dates in the history of the industry have still to be recorded. About 1860 the Ougrée Company employed on a large scale the oolitic iron ores, which are found in considerable quantities near Couthuin, in the province of Namur. This ore is still worked, and was for many years one of the chief sources of supply of the blast-furnaces. At the same epoch the Cockerill Company started at Seraing the manufacture of crucible steel. In 1855 the important improvement of recovering blast-furnace waste gases was introduced; in 1863 the Cockerill Company, always to the forefront in progress, constructed the first Bessemer converters and rolled in the same year the first steel rails, for which the Belgian Government paid up to

£17, 12s. per ton in 1874, although about 1895, at a time of intense crisis, the price dropped to about £3, 12s. per ton, f.o.b. Antwerp. At Liége in 1872 the first open-hearth regenerative furnace was introduced by the Schlessin Company. From 1870 to 1880 a complete revolution again transformed the Belgian iron industry, partly owing to the mines being exhausted and partly owing to the opening up of rich deposits of ore in Lorraine and Luxemburg. The ore is comparatively poor, but the gangue contains the necessary fluxes for smelting, and the treatment is consequently economical. From 1875 these foreign ores were used on a large scale for the manufacture of ordinary pig iron, and Spain supplied almost exclusively the ore for steel-making. At the present moment about eight-tenths of the ores treated in the Belgian blast-furnaces are imported. Another important date in the annals of the history of the iron industry is that of the application of the Thomas and Gilchrist process for the dephosphorisation of pig iron discovered in 1878. The Angleur Company introduced the process in 1879 and was therefore in a position to treat ores containing phosphorus. This process was not adopted generally in Belgium until the patent rights expired in about 1885, and then the manufacture of steel almost entirely replaced that of iron. Finally, one of the most recent improvements in the working of blast-furnaces is the utilisation of blast-furnace gases directly in gas-engines, and the Cockerill Company erected in 1897 at Seraing two gas-engines of 200 horse-power which are still working. There is an increasing tendency to introduce the driving of rolling-mills by electricity. Electric motors of 500 horse-power drive large rolling-mills, and it is possible to foresee the time when, owing to the complete utilisation of the blast-furnace gases and to the transmission of power by electricity, all works will be able to do without coal, with the exception of the coke used in the blast-furnace, and not a single pound of coal will be burnt under the boilers to transform the ore into the finished product.

In order to form an exact idea of the progress realised in the methods of production of iron, or rather pig iron, it is necessary to retrace the most important stages from remote times to the present day. Belgium has naturally not arrived at the colossal productions attained in the United States, but the position occupied by the Belgian iron industry was at one time the first of all, and at the present time is still a very creditable one. The first trustworthy figures in ancient times date back to 1546, and it is known that the furnaces employed at that epoch produced about 650 pounds of iron in twenty-four hours. Towards the end of the sixteenth century, the production increased considerably without exceeding, however, as a maximum 3 tons per day. The blast-furnaces of Chanxhe on the banks of the Ourthe, and those of Férot produced 876,000 pounds yearly, or about 438 tons. In 1750 a considerable advance was obtained, and the Chimay blast-furnace produced about 700 tons per annum. The blast-furnace of the Cockerill Company at Seraing, which has already been mentioned, was a remarkable example of progress and had a daily production of about 10 tons, or about 3000 tons annually. In 1848 a production of 25 tons per day was considered satisfactory, and the blast-furnaces of the Esperance

Company and those of the Cockerill Company in 1860 produced 5400 tons yearly; those of Schlessin, 6000 tons; those of Ougrée, 7000 tons; and the record was held by those of Grivegnée, which produced 9000 tons, or about 30 tons daily. About 1870 Belgium was at the head of the pig-iron producing nations of the world: the average annual production of a blast-furnace being 12,000 tons, whilst in Great Britain it was only 9150 tons, in Germany only 7000 tons, in the United States only 6500 tons, and in France only 4430 tons. In 1880 Belgium still held the record with an average annual production of nearly 20,000 tons, followed in order by England, 14,000 tons; Germany, 11,000 tons; the United States, 8750 tons; France, 8600 tons. Ten years later, in 1890, the United States with the rich ores of Lake Superior, and the hard coke of Connellsville, surpassed the countries of the old world and reached an average annual production of 30,000 tons, while Belgium was still at the head of Europe with 22,000 tons, followed by Germany with 21,000 tons; by England with 19,500 tons; and by France with 16,500 tons. Germany for the first time in 1900, owing to the enormous development of the minette district, held the European record with 31,000 tons annually as against Belgium with 27,000 tons, 22,500 tons for England, and 23,000 tons for France. For the same year the production of the United States had doubled, and amounted to 60,000 tons. At the present time the average yearly production in Belgium may be estimated at 32,755 tons, which was the production in 1905; this gives Belgium the third place after the United States, which have attained, according to the press, the enormous average of 100,000 tons; and after Germany, which exceeded 40,000 tons; but still before Great Britain with 26,000 tons, and France with 25,000 tons. The production of the latest blast-furnaces erected by the Cockerill Company and at Couillet attain 180 tons daily, or over 6500 tons yearly, and new blast-furnaces are planned by the Cockerill Company for about 200 tons daily, and at the Sambre and Moselle works to produce 250 tons daily, or 90,000 tons per annum. As the production of the blast-furnaces increased, their number diminished: in the United States, from 410 in 1873 to 182 in 1902; in Germany, from 297 in 1875 to 264; in England, from 661 to 349; in France, from 266 to 114; and in Belgium from 46 to 30 in 1870, to 27 in 1892, to rise again to 42 in 1905. The United States export about 7 per cent. of their production, France 10 per cent., Germany 33 per cent., while Belgium consumes only 20 per cent., and consequently exports nearly 80 per cent., including manufactured products.

SECTION ON METALS.

The work of the sections began on September 4, and was continued on September 5 and 6. The amount of work to be dealt with was so considerable that three sections were formed, A dealing with metals, B with building stone and cement, and C with other materials. Altogether there were twenty-seven reports of committees and forty-five original papers, the greater portion of which were submitted to the section on metals. Mr. J. Magery (Namur) presided over this section, and he was supported by honorary presidents, representing the various nationalities present, and including Messrs. Popper (Austria), Saladin (France), Wedding (Germany), Brough (Great Britain), Hackstroh (Holland), Chernoff (Russia), Tonello (Spain), and Brinell (Sweden). The following are brief notes on the various reports presented :—

Problem 1.—Dr A. Rieppel (Nuremberg) reported on the introduction of international specifications, giving particulars of the progress made in various countries in the introduction of standard specifications. The report was adopted, and the committee was requested to continue its investigations.

Problem 2.—W. Ast (Vienna) reported on methods of inspecting and testing in order to ensure uniformity in deliveries of iron and steel.

Problem 4.—R. Krohn (Danzig) reported that it was not feasible to establish standard welding tests. The Congress, however, expressed the wish that the problem should be further studied, and that opportunity should be given for carrying out scientific researches on the nature of welding.

Problem 6.—E. Heyn (Berlin), reporting on the value of etching malleable iron for the investigation of structure, showed that examination by the unaided eye gave valuable information as to the character of quenched high-carbon steel.

Problem 25.—Dr. Richard Moldenke (New York) pointed out that it was proposed in 1901 that efforts should be made to establish uniform methods of testing cast iron and finished castings. The subject was studied by a commission, who report that owing to the imperfect system in vogue in Europe and America, little can yet be expected from their first effort to prepare specifications for the testing of iron. Germany retains the old long bars in some measure, and carries out elaborate tests with them, while America has cut loose from the old methods and developed a system which would take into account the heat treatment of the metal and yet free the foundry industry as much as possible from troublesome requirements. The founder, in his daily occupation, is left to test his metal as he wishes, and an "arbitration bar," so called, cast under conditions as nearly perfect as can be made without unessential complications, stands between maker and buyer when a dispute arises and the quality of the metal is questioned. In Germany there have been adopted specifications for machinery castings, columns, and pipes. In the United States of America specifications for general castings, locomotive-cylinders, malleable castings, car-wheels, pipe and pig iron for foundry purposes, and specifications for coke are now being prepared. Regarding the methods of testing, the peculiar nature of cast iron precludes the use of the tensile test for commercial purposes. In fact, only with the most accurately adjusted testing-machines can trustworthy tests be made. Hence the German specifications have omitted this test altogether, while in America the test appears practically under protest. The transverse test seems to be the one most generally accepted. Impact tests have not so far proved their value in the foundry industry, neither have punching or shearing disclosed new avenues of research.

Problem 26.—E. Sauvage (Paris) reported on impact tests with notched bars, and there was an animated discussion as to the value of this method of testing, the Congress agreeing that the impact bending test with notched bars appeared to be capable of yielding very interesting results.

Problem 27.—J. A. Brinell (Stockholm) and Gunnar Dillner (Stockholm) presented a summary of the results of applications of the Brinell hardness test which had come under the notice of the authors. The paper is divided into three sections, dealing respectively with (1) researches concerning methods for carrying out ball tests; (2) researches as to the relation between the results obtained by ball tests and those obtained by tensile tests; and (3) machines and measuring-instruments for ball tests. The results of experiments carried out by Benedicks for determining the influence due to varying the pressure and diameter of the test ball are given, followed by a hitherto unpublished report by Mr. J. O. Roos on impact ball tests. In the researches concerning the relation between the results obtained by ball tests and those obtained by tensile tests it was found that very different hardness numbers were obtained according to whether the direction of the pressure on the ball was parallel with the fibres or across them. In the former case the investigators obtained greater hardness numbers and therefore smaller coefficients than in the latter case. In all Brinell's trials the direction of the pressure on the ball was parallel with the fibres. The paper further dealt with the trials carried out by Charpy, with Swedish steel, and gave tables showing his results.

There was a keen discussion following the reading of this report, and it was finally resolved unanimously that it was desirable that, in addition to tensile tests, Brinell hardness tests should be made as frequently as possible with a view to recording information.

Problem 36.—W. Ast (Vienna) submitted a report on international researches in the microscopic examination of iron. The etching test was recommended for preliminary examination.

Problem 37.—F. Osmond and G. Cartaud (Paris) submitted an interesting report on the progress of metallography since the Budapest Congress of 1901.

In addition to the Reports of Committees, the following papers were submitted to the section on metals:—

1. H. WEDDING.—"Alloys of nickel and iron."
2. O. BOUDOUARD.—"The allotropic transformations of nickel steels."
3. O. BOUDOUARD.—"Determination of the points of allotropic transformation in iron and its alloys by measurement of the variations in their electrical resistance at different temperatures."
4. L. FRAICHET.—"New magnetic test-methods."
5. C. J. SNYDERS and P. A. M. HACKSTROH.—"Observations regarding the mechanical examination of iron by means of drop-tests with notched bars."
6. A. MESNAGER.—"Tests upon notched bars carried out in the laboratory de l'Ecole des ponts et chaussées, Paris."
7. P. BREUIL.—"Examination of various metals by Brinell's method."
8. F. BARBIER.—"Remarks on the influence of the shape of the saw notch in the present method of testing for fragility."
9. S. DROUGININE.—"Determination of the degree of fragility and of homogeneity of rail-steel by impact-tests with notched bars."
10. G. CHARPY.—"Testing metals by bending notched bars."
11. R. GUILLERY.—"Communication on methods for the rapid testing of metals."
12. L. BACLÉ.—"Punching as a testing method."
13. F. OSMOND, Ch. FRÉMONT et G. CARTAUD.—"The phenomena of deformation and rupture in iron and mild steel."
14. K. HATT.—"Experiments on lead and copper subjected to compression in three impact machines."
15. A. GAGARINE.—"A new apparatus for automatically drawing the load-strain diagram due to impact."
16. A. GAGARINE.—"A new dynamometer. Limit of elasticity used for measuring forces and description of a machine for compression-, tensile- and bending tests."
17. G. CHARPY.—"Influence of temperature on the resistance of metals."
18. ST. GÁLLIK.—"The significance and importance of contraction as a test for quality, especially in estimating the malleability of metals."

SECTION OF CEMENTS.

The second section, dealing with cements, was under the presidency of Mr. M. Levie (Charleroi). The subjects discussed included the determination of the adhesive force of hydraulic cement, the determination of the weight of a litre of cement, and the behaviour of cement in sea-water. It was decided to appoint a committee to inquire into reinforced concrete.

MISCELLANEOUS SECTION.

The third section, under the presidency of Mr. E. Roussel (Malines), devoted attention to tests of paints, linseed oil, wood, bitumen, asphalt, and india-rubber.

Problem 17.—M. Gary (Berlin) reported on methods for testing pipes.

Problem 18.—E. Ebert (Munich) reported on methods of testing the protective power of paints used on metallic structures.

Problem 22.—N. Belelubsky (St. Petersburg) reported on the unification of methods of testing materials.

Problem 34.—G. Lunge (Zürich) reported on the uniform nomenclature for bitumen.

Printed copies of the reports and papers submitted to the Congress may be consulted in the Institute library.

NOMENCLATURE OF IRON AND STEEL.

The report of Committee 24, presented by H. M. Howe (New York), chairman, and Albert Sauveur (Harvard University), secretary, gave the following definitions:—

Alloy Cast Irons.—Those which owe their properties chiefly to the presence of an element (or elements) other than carbon.

Alloy Steels.—Those which owe their properties chiefly to the presence of an element (or elements) other than carbon.

Basic Pig Iron.—In America, pig iron containing so little silicon and sulphur that it is suited for easy conversion into steel by the basic open-hearth process. It is restricted to pig iron containing not more than 1·00 per cent. of silicon.

Bessemer Pig Iron.—That which contains so little phosphorus and sulphur that it can be used by itself for conversion into steel by the original or acid Bessemer process. In America, this term is restricted to pig iron containing not more than 0·10 per cent. of phosphorus.

Bessemer Steel.—Steel made by the Bessemer process, whether its carbon content is high, low, or intermediate.

Blister Steel.—Steel made by carburising wrought iron by heating it in contact with carbonaceous matter. It might also be made by so carburising a low-carbon steel.

Cast Iron.—Generically, iron containing so much carbon, or its equivalent, that it is not malleable at any temperature. Specifically, cast iron in the form of castings, other than pigs, or remelted cast iron suitable for casting into such castings, as distinguished from pig iron, *i.e.* cast iron in pigs, &c. (See Pig Iron.) The committee recommends drawing the line between cast iron and steel at 2·20 per cent. carbon, for the reason that this appears from the results of Carpenter and Keeling to be the critical percentage of carbon corresponding to the point "a" in the diagrams of Roberts-Austen and Roozeboom. As to the signification of this critical point, the committee is not prepared to express an opinion.

Cast Steel.—The same as crucible steel; obsolescent, and to be avoided because confusing, and because it offers a temptation to fraud.

Cemented Steel.—The same as blister steel.

Charcoal Hearth Cast Iron.—Cast iron which has had its silicon and usually its phosphorus removed in the charcoal hearth, but still contains so much carbon as to be distinctly cast iron.

Converted Steel.—The same as blister steel.

Crucible Steel.—Steel made by the crucible process, whether its carbon content is high, low, or intermediate.

Grey Pig Iron and Grey Cast Iron.—Pig iron and cast iron in the fracture of which the iron itself is nearly, or quite, concealed by graphite, so that the fracture has the grey colour of graphite.

Hæmatite Pig Iron.—Originally pig iron made from the hæmatite ores of England, which happen to be so free from phosphorus and sulphur that the pig iron made from them can be used by itself for the acid-Bessemer process. By association, it has come to mean any pig iron thus relatively free from phosphorus and sulphur. The term is not used in America, and is undesirable.

Hot Metal or Direct Metal.—The molten cast iron from the blast-furnace before it has been allowed to solidify.

Ingot Iron.—Steel cast into an initially malleable mass and containing so little carbon or its equivalent that it does not harden greatly on sudden cooling. The word is rarely used in England, "mild steel" or "low-carbon steel" or "soft steel" being generally used in its place. In America, the line between soft steel and half-hard steel is usually drawn at a carbon content of about 0·20 per cent.

Ingot Steel.—Steel cast into an initially malleable mass and containing so much carbon or its equivalent that it hardens greatly on sudden cooling. The word is rarely used in England, but "hard steel," "high-carbon steel," or "half-hard steel" are used in its place.

Malleable Castings.—Castings of malleable iron, which see.

Malleable Cast Iron.—Iron which, when first made, is cast in the condition of cast iron, and is made malleable by subsequent treatment without fusion. Although the English name of this variety suggests that it is cast iron, it is not truly a variety of cast iron, but rather forms an independent species of iron, because it lacks the essential property of cast iron, viz. its extreme brittleness. Though the term "malleable castings" is very common, the term "malleable cast iron" is very rarely used. The common but inexcusable term, we regret to say, is "malleable," pronounced "mallable," used as a substantive.

Malleable Iron.—The same as wrought iron. Used in Great Britain, but not in the United States, except carelessly, as meaning "malleable cast iron."

Malleable Pig Iron.—An American trade name for the pig iron suitable for converting into malleable castings through the process of melting, treating when molten, casting in a brittle state, and then making malleable without remelting. The term should be used with care to avoid confusion. This material is also called in trade in America "malleable iron"; but this use should be avoided, because "malleable iron" has the older and (in Great Britain) firmly established meaning of "wrought iron."

Mottled Pig Iron and Mottled Cast Iron.—Pig iron and cast iron, the structure of which is mottled, with white parts in which no graphite is seen, and grey parts in which graphite is seen.

Open-hearth Steel.—Steel made by the open-hearth process, whether its carbon content is high, low, or intermediate.

Pig Iron.—Cast iron which has been cast into pigs direct from the blast-furnace. This name is also applied to molten cast iron which is about to be so cast into pigs, or is in a condition in which it could readily be cast into pigs.

Plate Iron.—A name applied in Great Britain to refined cast iron.

Puddled Iron.—Wrought iron made by the puddling process.

Puddled Steel.—Steel made by the puddling process, and necessarily slag-bearing. (See Weld Steel.)

Refined Cast Iron.—Cast iron which has had most of its silicon removed in the refinery furnace, but still contains so much carbon as to be distinctly cast iron.

Shear Steel.—Steel, usually in the form of bars, made from blister steel by shearing it into short lengths, piling, and welding these by rolling or hammering them at a welding heat. If this process of shearing, piling, &c., is repeated, the product is called "double shear steel."

Steel.—Iron which is malleable at least in some one range of temperature, and in addition is either (*a*) cast into an initially malleable mass; or (*b*) is capable of hardening greatly by sudden cooling; or (*c*) is both so cast and so capable of hardening. Variety *a* includes also molten iron, which, if cast, would be malleable, as do its two sub-varieties, "ingot-iron" and "ingot-steel." (Tungsten steel is malleable only when red-hot.)

Steel-Cast (adjective).—Consisting of solid Bessemer, open-hearth, crucible, or other slagless steel, and neither forged nor rolled; applied to steel castings. For instance, a "steel-cast" gun is a gun which is a steel casting, *i.e.* which has been neither forged nor rolled. To call it a "cast steel" gun would imply that it was made of crucible steel, to which the term "cast steel" is restricted.

Steel Castings.—Unforged and unrolled castings made of Bessemer, open-hearth, crucible, or any other steel. Ingots and pigs are, in a sense, castings; the term "steel castings" is used in a more restricted sense, excluding ingots and pigs, and including only specially shaped castings, such as are generally used without forging or rolling. They may, however, later be forged, *e.g.* under the drop press, when they cease to be "castings" and become "drop forgings," or, if only part is forged, then they are partly forgings and partly castings.

Washed Metal.—Cast iron from which most of the silicon and phosphorus have been removed by the Bell-Krupp process without removing much of the carbon, so that it still contains enough carbon to be classed as cast iron. The name "washed metal" is extended to cover this product even if its carbon is somewhat below the proper limit for cast iron.

Weld Iron.—The same as wrought iron. Obsolescent and needless.

Weld Steel.—Iron containing sufficient carbon to be capable of hardening greatly by sudden cooling, and in addition slag-bearing, because made by welding together pasty particles of metal in a bath of slag, as in puddling, and not later freed from that slag by melting. The term is rarely used.

White Pig Iron and White Cast Iron.—Pig iron and cast iron in the fracture of which little or no graphite is visible, so that their fracture is silvery and white.

Wrought Iron.—Slag-bearing, malleable iron, which does not harden materially when suddenly cooled.

Wrought Steel.—The same as weld steel. Rarely used.

The following are definitions of names designating special sizes or shapes of iron and steel:—

Bar Iron.—Wrought iron in the form of bars, rods, &c.

Muck Bar.—The rough bars, usually 1 inch thick and about 4 inches wide, made by the first rolling of a ball of puddled iron.

Merchant Bar.—Wrought iron in the form of merchantable bars or rods made by shearing muck bar into short lengths, piling it and rolling or forging it at a welding heat.

Bloom.—1. A large bar, drawn from an ingot or similar mass, for further manufacture. 2. A rough bar of wrought iron drawn from a Catalan or bloomery ball for further manufacture.

Billet.—A small bar drawn from a pile, bloom, or ingot for further manufacture. The committee recommends that the line between blooms and billets be drawn at the size of 5 inches square, as representing common custom.

Slab.—A flat piece or plate, with its largest surfaces plane, drawn or sheared from an ingot or like mass for further treatment.

In conclusion, the view is expressed that it would be well to decide on a definite carbon content to serve as a boundary line between ingot iron and ingot steel, between puddled iron and puddled steel, and between any other varieties of wrought iron and weld steel. Two plans have been considered. One is to draw this line at 0·32 per cent. carbon or its equivalent in other elements, for the reason that this carbon content appears to correspond to the critical point O in the diagrams of Roberts-Austen and Roozeboom. This has the merit of corresponding to a definite physical boundary. The other plan is to draw the boundary at 0·20 per cent. of carbon, because this is a convenient place to separate the important classes "soft steel" and "half-hard steel," so that if this point was adopted "ingot iron" would be synonymous with "soft steel," and "ingot steel" would be equivalent of the two classes "half-hard steel" and "hard steel."

The report was received and adopted by the Congress, and the committee was requested to continue their labours with a view to securing the foreign equivalents to the terms defined. It was also suggested that the report be submitted to the Iron and Steel Institute and kindred societies for their consideration.

METALLOGRAPHY.

The Congress concluded with a lecture by Professor H. Le Chatelier (Paris) on "Practical Applications of Metallography." He commenced by showing that metallography, even in its simplest aspects, may be employed as a useful adjunct to chemical analysis. Amongst the services rendered by metallography are that it enables the mechanical structure of the metals under examination to be ascertained. Thus their degree of porosity, the presence of included slag, of graphite or of sulphide of iron, can be readily recognised. In the daily work of a factory or steelworks metallography finds useful application. Chemical analysis, pyrometry, and the microscopic examination of metals all tend to regularise the diverse factors upon which the quality of the finished product depends. Metallography furnishes information of much the same nature as the other branches of investigation employed in works practice, but it may at times be usefully substituted for the lengthier processes of chemical analysis. Thus, in the case of brittle steel rails, chemical analysis may show the brittleness to arise from too high a percentage of phosphorus, while, on the other hand, microscopic examination may reveal a coarse structure due to the material having been rolled at too high a temperature. In the manufacture of shafts and axles, metallography will show any defects in the thermal treatment which the metal may have undergone. The lecturer gave a number of examples showing the utility of this mode of examining materials drawn from a number of metals other than steel. He showed in each case the practical bearing which metallography had on the processes of manufacture to be adopted in order to secure the best results. An examination of the microstructure of metals would afford an excellent basis for a classification of pig irons and of certain steel alloys, the chemical and physical properties of which might be such as to render any system of classification based upon other considerations a matter of difficulty.

While it was incontestable that metallography would prove of great benefit in works practice, it was necessary to judge it from the standpoint of its comparative cost in relation to other means of investigation at the disposal of metallurgists. In many works there were now established palatial metallographical laboratories with expert staffs, aided by engineers, photographers, and others. The cost of such an establishment might be very heavy, and it was, therefore, only right to inquire whether the value of the information which could be furnished in such a laboratory would justify the expenditure entailed, particularly in view of the fact that in many instances the observation of a simple fracture might apparently furnish as much information. As a matter of fact, it would be unnecessary in the future for the study of metallography to entail the heavy charges which it did at present. It was fortunate for the progress of the science that the management of so many works had been willing to undertake such costly installations. If a lavish expenditure were really necessary, that would in itself be a condemnation of metallography. Indeed, a metallographical installation might be obtained at considerably less cost than a chemical laboratory, not only as regards first charges, but also as regards the expenses of maintenance and the salaries of staff. The lecture was illustrated by thirty-six lantern photographs.

An interesting feature of the Congress was a small laboratory installed to illustrate modern methods of testing, under the direction of Prof. H. Le Chatelier, Dr. Guillet (Paris), and Prince Gagarine (St. Petersburg).

VISITS AND EXCURSIONS.

The afternoons were devoted to various excursions, including one to Antwerp on September 5, when the roadstead and the river Scheldt, from Hoboken to Astruwel, were inspected, and one to Malines on September 6, when the testing-station of the Belgian State Railways was visited. A banquet at the "Grande Harmonie" and a reception by the Mayor and the Corporation of Brussels in the Town Hall closed the proceedings in the capital. At the banquet speeches were delivered by Messrs. Berger, Mesnager, Brough, Roussel, Greiner, and Wedding. On September 7 the works of the John Cockerill Co. at Seraing were visited, and on September 8 and 9 the members of the Congress were entertained at Ostend, and the new harbour of Zeebrugge was inspected, while in the evening there was a *grande fête artistique* in the Kursaal, and a performance in the Theatre Royal. A luncheon at the Casino in Ostend at the invitation of the municipality brought the proceedings to a close.

It was decided that the next Congress should be held in 1909 in Copenhagen, under the presidency of Mr. A. Foss, President of the Society of Danish Engineers.

Mr. J. E. Stead (Middlesbrough), Mr. Cano y de Leon (Madrid), and Mr. Axel Wahlberg (Stockholm) having resigned their seats on the Council, Mr. Bennett H. Brough (London), Colonel Marva y Mayer (Madrid), and Mr. Gunnar Dillner (Stockholm) were elected in their places. The other members of Council are Messrs. N. Belelubsky (St. Petersburg), A. Martens (Berlin), B. Kirsch (Vienna), C. von Banovits (Budapest), J. Bennetti (Bologna), L. Bienfait (Amsterdam), C. B. Dudley (Altoona, Pennsylvania), A. Greiner (Seraing), H. I. Hannover (Copenhagen), S. A. Lund (Christiania), A. Mesnager (Paris), and F. Schüle (Zurich). The secretary is Mr. E. Reitler (Nordbahnstrasse 50, Vienna).

OBITUARY.

JOHN DEVONSHIRE ELLIS, Vice-President of the Iron and Steel Institute, died at his residence, Sparken, Worksop, on Sunday morning, November 11, 1906, at the age of eighty-two years. Mr. Ellis was one of the makers of modern Sheffield, and for over fifty years he was a leader in every development of the heavy steel trades. He was the son of a Birmingham brass manufacturer, and was educated at King Edward VI.'s School in that town, under the headmastership of Dr. Jeune. At twenty-four years of age he was admitted to partnership with his father and brother, and spent seven years in the superintendence of the engineering and manufacturing departments of the firm. In 1854 he left Birmingham for Sheffield to devote himself to the steel trade on his own account. He joined Mr. (afterwards Sir John) Brown in the purchase of a small steelworks. Mr. Brown had already been engaged for some years in business in the town as a manufacturer of railway springs and buffers; and there was shortly afterwards admitted a third partner, the late Mr. William Bragg. The enterprise began in a small works covering less than three acres, with a joint capital of about £15,000, 250 employes, and an annual output of about 5000 tons, value £30,000. The railway developments of the fifties gave the new firm its first great lift, for Mr. J. D. Ellis was the one man among the three partners who realised the importance of the invention of the firm's neighbour, Mr. Henry Bessemer, and persuaded his associates, against their own judgment, to enter on the manufacture of steel rails by the Bessemer process, under licence from the inventor. The firm did well out of steel rails for many years, until economic conditions took the industry away to the coast. A still more important chapter in Mr. Ellis's history is his part in the development of the manufacture of armour-plates, and it was at his works that the first armour-plate was rolled. In 1859 his firm started rolling and welding iron plates till the required thickness for ships' protection was attained. Later, when armour of this description was superseded, Mr. Ellis brought out the "Ellis" compound armour, consisting of plates of wrought iron with a hard steel face half the thickness of the iron, the steel and iron being made separately and welded together by a process of his own invention. The next notable step in the improvement of armour was effected by the introduction of the principle of cementation, a combination of the cementation and chilling processes being the main feature of the Ellis-Tresidder armour, which marked a great advance in shot-resisting power. The well-known Ellis-Eaves system of induced draught was also the result of his experiments; and he made numerous improvements in workshop plant. The firm of John Brown & Co., of which he was chairman at the time of his death, became a limited company in 1864, with a capital of £1,000,000 sterling; the total capital is now close on £3,000,000. The firm employs about 16,000 men, with a yearly wage bill of a million and a quarter sterling. Sir John Brown retired in 1870, and from that date down to his death Mr. Ellis remained the head of the firm, and his regular daily attendance, scarcely ever interrupted for a holiday, continued down to after his eightieth year. In 1867 the King of Sweden conferred upon Mr. Ellis the Cross of the Order of Wasa. He was a member of the Institution of Civil Engineers and of the Cutlers' Company. He was elected a member of the Iron and Steel Institute in 1875, and was awarded the Bessemer Gold Medal in 1889 for his services to metallurgy. In 1888 he was elected a member of Council, and in 1901 a Vice-President of the Institute. During the visit of the Institute to Sheffield in 1905 he acted as a member of the Local Reception Committee, and received the members on the occasion of their visit to the Atlas Works, despite the fact that his health was then failing. He subsequently spoke at the luncheon given at the Norfolk Works.

Henri de Wendel, Bessemer Gold Medallist, died at the Castle of Vaugien on October 12, 1906. He was the head of the well-known De Wendel Ironworks, situated on both sides of the Franco-German frontier in Lorraine. He was born in 1844, and as his father died in 1870, shortly before the outbreak of the Franco-German war, he, with his younger brother Robert and his cousin Baron Theodore de Gargan, took over the onerous task of directing the great works in circumstance of exceptional difficulty. With tact and skill he was able not only to keep the works going, but even to bring them to a higher degree of efficiency. In 1880 he built ironworks at Joeuf, on the French side of the frontier, in order to keep the French market. On the invention of the basic Bessemer process he built new steelworks at Hayingen and at Gross-Moyoeuvre. Extensive rolling-mills were also built, and much attention was devoted to the utilisation of blast-furnace gases. Appreciating the importance of a good supply of iron ore, he put down bore-holes in France and found a considerable extension of the minette bed to the west. He also developed the coal industry of Lorraine, and in 1901 began sinking new shafts in Westphalia. At the present time the number of workmen employed by the firm exceeds 20,000. He was elected a member of the Iron and Steel Institute in 1872, and in 1900 received the Bessemer Gold Medal in recognition of his conspicuous services to metallurgy.

James A. Burden died on September 23 at his home in New York City, at the age of seventy-three. He had been an invalid for some time, and had recently returned from a voyage in Europe, undertaken for the sake of his health. He was born in Troy, New York, in 1833, and was educated at the Rensselaer Polytechnic Institute, on leaving which he became a foreman in the Burden Ironworks, founded by his father, Henry Burden. He was president of the Burden Iron Company at the time of his death. He took an active interest in engineering and metallurgy, and was the author of many inventions, amongst others, machinery for making blooms, a method of fettling puddling furnaces, and an electrical ore separator. For some time he acted as president of the Hudson River Ore and Iron Company. He was also vice-president and a director of the Eastern Steel Company, and a director of the Port Henry Iron Company. He was a member of the Engineers' Club of New York, of the American Society of Civil Engineers, of the American Institute of Mining Engineers, and of the American Society of Mechanical Engineers. In 1890, when the members of the Iron and Steel Institute visited America, he was a member of the New York reception committee. On the occasion of the second visit in 1904, he was elected chairman of the New York reception committee. In that capacity he contributed in no small measure to the success which attended the meeting, and entertained the president, and council, and the reception committee at dinner at the Metropolitan Club. He was the oldest American member of the Iron and Steel Institute, having been elected a member in 1870.

Louis Cassier died on Sunday morning, July 1, 1906, as the result of a disaster which occurred on that date to an express train on the South-Western Railway, at Salisbury. He was forty-three years of age, and was born in Boston, Massachusetts, in June 1863. At the age of fifteen he left his native city and became identified with the business of publishing, and secured a position of prominence in the field of engineering publications. In November 1891 he published the first issue of *Cassier's Magazine*, in New York, and in 1894 the London edition of this periodical made its appearance. In 1899 the English business was made into a limited company under the style of the Louis Cassier Company, Limited. In 1903 Mr. Cassier acquired the *Electrical Age*, a magazine published in New York. He was a member of several of the learned societies in England and in America. He was elected a member of the Iron and Steel Institute in 1903.

Ernest Farnworth, who was widely known in connection with the iron trade of South Staffordshire, died at his residence, Goldthorn Hill, Wolverhampton, in August 1906, after an illness lasting over eighteen months. He was the son of the late Mr. William Farnworth, who was for a long period intimately associated with the firm of Messrs. Baldwin, the owners of the Swindon Ironworks, near Wombourne. He remained with his father at those works until he married the daughter of the late John Jones, when he went to manage a section of the Corrugated Iron Works, Walsall Street, Wolverhampton, better known as the Shrubbery Sheet Iron and Steel Company. He was closely associated with the scheme for the removal of a portion of the works to Ellesmere Port, near Birkenhead, but he did not live to see the scheme completed. He was elected a member of the Iron and Steel Institute in 1894.

David Henry Haggie died at Harrogate on September 19, 1906, aged fifty-six. He had been ailing, and left Sunderland a few weeks ago for his Harrogate residence. It is believed that the strain of the last general election, at which he stood as a Conservative candidate, brought about his fatal illness. He came of a well-known Durham family, and had extensive property in Sunderland. He was a vice-president of the Northern Tariff Reform Federation, and chairman of the Sunderland Conservative Association. Some years ago he took over the wire-rope works of the late R. Hay at Monkwearmouth, Sunderland, which he carried on ever since. He was elected a member of the Iron and Steel Institute in 1884.

Camille Mercader died September 7, 1906, in St. Joseph's Hospital, Philadelphia, as the result of an operation. He was one of the most eminent and popular engineers in Pittsburg. He was born in Hungary, near Budapest, forty-three years ago, and was educated at the polytechnic school at Dresden, Germany. He went to the United States in 1889, and for a short time was engaged in the bridge business at Chicago. Later he proceeded to Pittsburg to become assistant to Charles M. Schwab, then superintendent of the Edgar Thomson Steel Works of the Carnegie Company at Braddock. He remained at Braddock during the Schwab administration, and later became assistant to the president of the company, and was engaged on special work. In 1892 he went to Hungary and built one of the largest steel plants in operation there. He was regarded as one of the most brilliant engineers, and one of his most recent inventions is that of a process to roll steel wheels for freight and passenger cars, which is being experimented with by the Pennsylvania and other important railroads. He also invented the hollow steel axle for steel cars. It was the intention of the Carnegie Company to make this equipment at the Howard Axle Works and at the Edgar Thomson Works. He was prominent socially, especially among the German engineers, and was always active when foreign engineers visited Pittsburg. He was president of the German Technical Society and a member of the Engineers' Society of Western Pennsylvania and the Union Club. He was elected a member of the Iron and Steel Institute in 1903, and contributed to the proceedings a paper on "Hollow Steel Axles."

Richard Pink died on September 23, 1906, at his residence in Hanover. Born in 1832 in London, he was the only son of William Pink, an architect, and on leaving school he entered his father's office. Subsequently he started engineering works in Sheffield, which he gave up in 1862, on the invention of the Bessemer process, to enter the works of Bessemer & Company, Sheffield, as a volunteer. Shortly after he received a leading position in that firm. In 1864 he was sent to the Hoerde Works to erect a Bessemer plant of three 3-ton converters. He was then appointed steelworks manager, a position he held until 1880. In 1879 he introduced the Thomas and Gilchrist process at Hoerde, where it was used for the first time in Germany. Reasons of health induced him to leave Hoerde and take up his residence in Hanover. There he discovered late in life his artistic talents, and did good work as a sculptor. In later years he took over the management of the Opaka Petroleum Company, and was until his death a member of the board of directors of the Thale Ironworks and of potash mining companies. In all these positions his advice was highly valued. He was elected a member of the Iron and Steel Institute in 1876, and in 1880 contributed to the proceedings a paper on dephosphorisation of iron in the Bessemer converter.

Sir Edward James Reed died on November 30, 1906, at his London residence, Savoy Court, Strand. Born at Sheerness on September 20, 1830, he, after serving his apprenticeship with a shipwright, entered the School of Mathematics and Naval Construction at Portsmouth. Leaving in 1852, he obtained a position in Sheerness Dockyard, but resigned on account of a dispute with the authorities, and then occupied himself with technical journalism, editing the *Mechanic's Magazine.* In 1860 he became first secretary of the newly founded Institution of Naval Architects, and in 1863 was appointed Chief Constructor of the Navy. At the time when he assumed this office the art of constructing ships of war was in a transition stage, and he did much to mould it on the lines along which it subsequently developed. The superiority of iron over wood as the material for the hulls had barely been established, and the methods in which it was employed were largely modelled on those practised with wood. Reed was quite clear as to the advantages of iron, and in the "bracket-frame" system of construction, first adopted for the *Bellerophon* (1865), he introduced a more effective method of utilising its special qualities. In regard to armour, the necessity for which was generally recognised, when his term of office began, as the result of experience gained in the Crimean war, he adopted the principle that the vital parts—boilers, engines, magazines, rudder, and steering gear—in addition to the heavy-gun positions, should be adequately protected. In the *Warrior*, the first sea-going ironclad, begun in 1859, there was a central citadel, 213 feet long, which was provided with 4½-inch armour, but the rest of the ship, which was in all 380 feet in length, was unprotected against injury from shot and shell. To remedy this weakness he advocated and used in his ships an armour belt extending the whole length at the water-line. In 1869 he expressed the opinion that, if any mistake had been made with reference to the introduction of turret-ships, and especially of monitors, into the British Navy, it had consisted in adopting them too rapidly rather than too slowly; indeed, it was his attitude towards turret-ships that led to his resignation in 1870. The *Devastation*, begun in 1869, embodied his idea of the best results obtainable on the turret plan. In her he solved the problem presented by the rigging by dispensing with sails altogether, and she was thus the first British sea-going battleship that relied solely on steam. He left the Admiralty in 1870. During his seven years' service the Navy had been increased by some forty iron armourclads, in addition to cruisers and other vessels, and subsequently, in the course of his practice as a naval architect, he was responsible for many other war-vessels. For Brazil, in 1872, he designed the *Independencia*, which, in 1878, was purchased by the British Government and called the *Neptune*. For Germany he planned the *Kaiser* and *Deutschland*, cruisers of about 7600 tons, both of which were built at Samuda's yard on the Thames, the latter being completed in 1875; and three cruisers for Japan a little later. For Chili he produced the cruising armourclads *Almirante Cochrane* and *Blanco-Encalada*, which were launched in 1874 and 1875, and it was at the behest of the same Power that more than a quarter of a century afterwards he designed the *Libertad* and the *Constitucion*, battleships, which were launched by the firms of Vickers, Sons & Maxim and Armstrong, Whitworth & Co. at the beginning of 1903, and which now form part of the British Navy as the *Triumph* and *Swiftsure*.

Sir Edward Reed entered Parliament as Liberal member for the Pembroke Boroughs in 1874, and at the general election of 1880 was returned for Cardiff District. This seat he retained until 1895, and he was again returned for it in 1900, but did not seek re-election in 1905. He was a Lord of the Treasury in Mr. Gladstone's Administration of 1886. He was made a K.C.B. in 1880, and in addition held several foreign orders and decorations. The Royal Society elected him a Fellow in 1876. He was the author of a considerable number of books, including "Shipbuilding in Iron and Steel" (1869); "Our Ironclad Ships" (1869); "The Stability of Ships" (1884); and "Modern Ships of War" (1885). He was elected a member of the Iron and Steel Institute in 1870.

Hugh William Waddle died on Monday, November 5, 1906, at Torquay. He was born in 1845, and was the eldest surviving son of the late John Roberts Waddle, the original inventor of the Waddle fan, and was prominently identified with the improvements which have been made of recent years in mining ventilation. He was a member of the Institution of Mechanical Engineers and of the Institution of Mining Engineers. He was elected a member of the Iron and Steel Institute in 1898.

Augustus Frederick Wiener died on July 5, 1906, at the age of sixty-eight. After a varied commercial career on the Continent and in England, he became connected with the metal industry, in the year 1900, as managing director of a company exploiting deposits of vanadium and silver lead ores in Spain. In the year 1902 he was appointed managing director of the New Vanadium Alloys, Limited, a company formed to acquire the vanadium portion of the business of the earlier company; and practically devoted the last six years to perfecting the methods of vanadium extraction and reduction at the company's works in Wales, and in extending the use of vanadium as an alloy of special steel. With what success he met is shown by the interesting papers on vanadium steel which have been read during the course of the last two years, at various institutions throughout Great Britain. He was elected a member of the Institute in 1903.

During the second half of 1905 the iron industry suffered serious losses by the deaths of eminent metallurgical authorities, who, though not members, took a constant interest in the work of the Iron and Steel Institute. The list includes James Dredge, C.M.G., editor of *Engineering*, who, on the occasion of the New York meeting in 1890, unveiled a monument to A. L. Holley, Bessemer Gold Medallist; Sir Richard Tangye, the head of the engineering firm bearing his name; Sir Thomas Richardson, Past-President of the North-East Coast Institution of Engineers; Lord Masham, colliery owner, economist, and inventor of several mechanical devices; Professor P. Curie, the eminent French chemist; Dr. Sprengel, the inventor of the laboratory pump; August von Borries, the Prussian authority on railways; Carl von Siemens, of the German firm of Siemens & Halske; Fritz Baum, the inventor of a coal-washing machine; Eduard Blass, author of papers on flame-temperature and on water-gas; J. B. Lebacqz, the Belgian ironmaster; G. Cartaud, author of papers on metallography; J. P. Wetherill, inventor of the magnetic concentrator; and Dr. S. P. Langley of the Smithsonian Institute, Washington.

ADDITIONS TO THE LIBRARY

DURING THE SECOND HALF OF 1906.

Title.	By whom Presented.
"Lloyd's Register of British and Foreign Shipping." Vol. I., Register; Vol. II., Appendix, with rules and regulations, 1906–1907. London. 1906.	The Committee.
"Metallgiesserei." By E. Stahl. 8vo, pp. 170. Freiberg, Saxony. 1906.	The Publishers.
"Das Bessemern von Kupfersteinen." By F. Mayr. 8vo, pp. 40. Freiberg, Saxony. 1906.	The Publishers.
"National Physical Laboratory: Report of the Observatory Department for the Year 1905." 8vo, pp. 43, Teddington. 1906.	The Director.
"Annual Statistical Report of the American Iron and Steel Association for 1905." 8vo, pp. 93. Philadelphia. 1906.	J. M. Swank.
"Purdue Engineering Review." No. 2, 1906. 8vo, pp. 106. Lafayette, Indiana. 1906.	The Director.
"Iron Ore Analysis Book for 1906." By W. H. Müller & Co. 16mo, pp. 34. London. 1906.	The Company.
"The Manufacture of Cartridge-cases for Quick-firing Guns." By Colonel L. Cubillo and A. P. Head. 8vo, pp. 791–853. (Reprint from the *Proceedings of the Institution of Mechanical Engineers*, 1905.)	B. W. Head.
"Kungl. Tekniska Högskolans Materialprufningsanstalt, 1896–1906." 8vo, pp. 83. Stockholm. 1906.	Gunnar Dillner.
"Aperçu des causes du développement industriel et commercial de ce pays." By J. Obozinski. 8vo, pp. 24. "Bian's Blast-furnace Gas Washer." Folio, pp. 10.	Baron C. von Thal.
Engineering Standards Committee. "British Standard Specification for Steel Conduits for Electrical Wiring: Report No. 31." Folio, pp. 9. "British Standard Nuts, Boltheads, and Spanners: Report No. 28." Folio, pp. 11. "British Standard Systems for Limit Gauges (running fits): Report No. 27." Folio, pp. 11. "Errors in Workmanship based on Measurements carried out for the Committee by the National Physical Laboratory: Report No. 25." Folio, pp. 15, with fourteen plates. "British Standard Specifications for Material used in the Construction of Railway Rolling Stock: Report No. 24." Folio, pp. 62. London. 1906.	The Committee.
"Bidrag till sveriges officiella statistik Kommerskollegii underdåniga berättelse för år 1905." Folio, pp. 25. Stockholm. 1906.	R. Åkerman.
Two framed photographs of the Iron and Steel Institute Dinner at Guildhall, July 27, 1906.	Fradelle & Young.
"Plates of the Britannia and Conway Tubular Bridges." Folio. "Working Drawings and Designs in Mechanical Engineering and Machine-making." Folio.	H. N. Funnell.
"Technical Thermometry." List No. 39. 4to, pp. 62. Cambridge. 1906.	Cambridge Scientific Instrument Co., Ltd.
"Syllabus of the Redruth School of Mines for 1906–1907." 8vo, pp. 45. Truro. 1906.	The Registrar.
"Report of the Proceedings of the Carnegie Dunfermline Trust for the Year 1905." 8vo, pp. 88. Dunfermline. 1906.	The Trustees.
"Programm der Königl. Sächs. Bergakademie zu Freiberg 1906–1907." 8vo, pp. 82. Freiberg. 1906.	The Registrar.

Title.	By whom Presented.
"Forty-second Annual Report on Alkali, &c., Works." 8vo, pp. 158. London. 1906.	The Board of Trade.
"Sundry Geological Problems." By G. Henriksen. 8vo, pp. 18. Christiania. 1906.	The Author.
"List of Official Appointments held in Great Britain and Ireland, in India and the Colonies." By R. B. Pilcher. 8vo, pp. 123. London. 1906.	The Registrar, Institute of Chemistry.
"Zentrale für Bergwesen. Bericht über das vierte Geschäftsjahr, 1905." 4to, pp. 9. Frankfurt. 1906.	The Secretary.
"Report of the Work of Committee 22, appointed for the Solution of the Problem, 'Unification of Testing Methods.'" 8vo, pp. 22. Vienna. 1906.	The International Testing Congress.
"Rapport Consulaire sur l'année, 1905." By G. H. Müller. 4to, pp. 272. Rotterdam. 1906.	The Consul-General.
"The Chemical Analysis of Iron." By Andrew A. Blair. 6th edition. 8vo, pp. 328. London. 1906.	The Publishers.
"Studien über den Thomas-Gilchrist Process." By J. von Ehrenwerth. 8vo, pp. 226. Vienna. 1881.	The Author.
"Das Berg- und Hüttenwesen auf der Weltausstellung in Chicago." By J. von Ehrenwerth. 4to, pp. 396, with eleven plates. Vienna. 1895.	The Author.
"The Production of Manganese Ores in 1905." By John Birkinbine. 8vo, pp. 29. "The Production of Iron Ores in 1905." By John Birkinbine. 8vo, pp. 38. Washington. 1906.	The Author.
"Metallurgy of Iron in the Periodicals of 1905." By M. A. Pavloff. 8vo, pp. 485–622. (In Russian.) St. Petersburg. 1906.	The Author.
"A Short Handbook of Sweden." Small 8vo, pp. 178. Stockholm. 1906.	The Librarian, The University, Upsala.
"Recent Practice in Cane-Sugar Machinery." By Perry F. Nursey. 8vo, pp. 38. (Paper read before the Society of Engineers, October 1, 1906.) London. 1906.	The Author.
"Geological Survey of Western Australia." Bulletins No. 21, 8vo, pp. 140; No. 22, 8vo, pp. 92.	The Director.
"Statistical Tables showing the Production and Consumption of Iron Ore and Pig Iron and the Production of Steel in the United Kingdom and the principal Foreign Counties in recent Years." Folio, pp. 29. London. 1906.	The Board of Trade.
"Mines and Quarries: General Report and Statistics for 1905." Part II.: Labour. Folio, pp. 51–126. Part III.: Output. Folio, pp. 127–286. London. 1906.	The Under-Secretary of State.
"The Iron Ore Properties in the Mayurbhanj State, India." By W. Selkirk. 4to, pp. 32. "The Tata Iron and Steel Company." Report by C. P. Perin and C. M. Weld. 4to, pp. 101. London. 1906.	B. J. Padshah.
"Missouri Bureau of Geology and Mines." 2nd Series. Vol. III., pp. 104. Vol. IV., pp. 120. Jefferson City. 1905.	The Director.
"The Indicator Handbook." By C. N. Pickworth. Small 8vo, pp. 130. Manchester. 1906.	Bennett H. Brough.
"Die wirtschaftliche Entwicklung der Gelsenkirchener Bergwerks-Aktiengesellschaft von 1873–1904." By B. Simmersbach. 8vo, pp. 96. Freiberg. 1906.	
"Der Reibungsprozess." By O. Witt. 8vo, pp. 42. Freiberg. 1906.	
"Transvaal Mines Department, Geological Survey." Memoir No. 2. 8vo, pp. 55. Pretoria. 1906.	
"L'Influence de l'Azote sur les propriétés du Fer et de l'acier. By A. Pourcel. (Reprint from the *Revue Universelle des Mines*, vol. xv. pp. 229.) Paris. 1906.	The Author.

Title.	By whom Presented.
"Manchester Steam Users' Association: Memorandum by Chief Engineer for the Year 1905." 8vo, pp. 51. Manchester. 1906.	Bennett H. Brough.
"Carboni Fossili Inglesi, Coke, Agglomerati." By G. Gherardi. 18mo, pp. 586. Milan. 1906.	
"Lloyd's Register of British and Foreign Shipping: Report of the Society's Operations during the Year ended 30th June, 1906." 8vo, pp. 14.	The Committee.
"Arbeitslohn und Unternehmergewinn im rheinisch-westfälischen Steinkohlenbergbau." By Dr. Jüngst. (Reprint from *Glückauf*, Nos. 37 and 40, 1906.) Essen-Ruhr. 1906.	The Author.
"Experiments on the Strength of Treated Timber." By W. K. Hatt. 8vo, pp. 31. Washington, D.C. 1906.	The Author.
"Some of the Relations of Railway Transportation in the United States to Mining and Metallurgy." By James Douglas. 8vo, pp. 19. (Reprint from *School of Mines Quarterly*, vol. xxviii., No. 1.)	The Author.
"Das Zusammenwirken von Beton und Eisen." By E. Probst. 4to, pp. 59. Berlin. 1906.	Bennett H. Brough.
"Die Abhängigkeit der Bruchlast vom Verbunde." By F. von Emperger. 4to, pp. 47. Berlin. 1906.	
"Transactions of the Civil and Mechanical Engineers' Society: 47th Session, 1905." London. 1906.	The Secretary.
"La Situation de la Grosse Métallurgie en France." By E. Saladin and G. Charpy. 4to, pp. 268–308. (Reprint from *Revue de Métallurgie*, vol. iii., No. 7, 1906.)	E. Saladin.
"Uber das Gleichgewicht und die Erstarrungsstrukturen des Systems Eisen-Kohlenstoff." By Carl Benedicks. 4to, pp. 33. (Reprint from *Métallurgie*, vol. iii., Nos. 12–14.)	The Author.
"Foreign Import Duties, 1906." 8vo, pp. 694. London. 1906.	The Board of Trade.
"Internal Energy." By John V. V. Booraem. 8vo, pp. 144. New York. 1906.	The Author.
"Transvaal Mines Department: Report of the Geological Survey for the Year 1905." Folio, pp. 114. Pretoria. 1906.	The Director.
"Chili et Bolivie, étude économique et minière." By Ferdinand Gautier. 8vo, pp. 229. Paris. 1906.	The Publishers.
"British Corporation for the Survey and Registry of Shipping: Additions and Corrections, October 1906." Obl. folio. Glasgow. 1906.	The Secretary.
"Grundriss der Eisenhüttenkunde." By H. Wedding. 8vo, pp. 392. Berlin. 1907.	The Author.
"Forty-eight Photographs of Iron Tests." Folio.	H. A. Allen (Geological Survey).
"Ferrum: Poème latin écrit en 1717." Par le P. Xavier de la Sante, et traduit en vers français par F. Osmond. Paris. 1906.	F. Osmond.
"Colonial Import Duties, 1906." 8vo, pp. 586. London. 1906.	The Board of Trade.
"Le Paraguay Décrit et Illustré: Étude sur le Progrès économique du Pays." By R. von Fischer-Treuenfeld and L. Rehwinkel. 8vo, pp. 81. Brussels. 1906.	The Consul-General for Paraguay.
"Commerce of the World, 1850–1905." 8vo, pp. 11. Philadelphia. 1906.	The Director, Philadelphia Commercial Museum.
"Instructions to Engineers of Timber Tests." By W. K. Hatt. 8vo, pp. 55. Washington. 1906.	The Author.
"Lägre Tariffer för Export och Transitogods på Sveriges Järnvägar." 8vo, pp. 167. Stockholm. 1906.	Sveriges Allmänna Exportförening.

INSTITUTIONS.

The Publications of the Institute are exchanged for those of the following Institutions:—

LONDON.

Board of Trade.
Chemical Society.
City and Guilds Institute.
Geological Society.
H.M. Patent Office.
Institution of Civil Engineers.
Institution of Electrical Engineers.
Institution of Mechanical Engineers.
Institution of Mining and Metallurgy.
Institution of Naval Architects.
Royal Artillery Institution.
Royal Institute of British Architects.
Royal Institution.
Royal Society.
Royal Statistical Society.
Royal United Service Institution.
Society of Arts.
Society of Chemical Industry.
Society of Engineers.
University College.

PROVINCIAL.

Birmingham University.
Cleveland Institution of Engineers.
Engineering Society, The University, Leeds.
Institution of Engineers and Shipbuilders in Scotland.
Liverpool Engineering Society.
Manchester Association of Engineers.
Manchester Geological and Mining Society.
Merchant Venturers' Technical College (Bristol).
Mining Institute of Scotland.
North-East Coast Institution of Engineers.
North of England Institute of Mining and Mechanical Engineers.
Royal Dublin Society.
Sheffield University.
South Staffordshire Ironmasters' Association.
South Wales Institute of Engineers.
Staffordshire Iron and Steel Institute.
University College of South Wales.
West of Scotland Iron and Steel Institute.

COLONIAL AND FOREIGN.

Colonial.

Australasian Institute of Mining Engineers.
Canadian Institute.
Canadian Mining Institute.
Canadian Society of Civil Engineers.
Department of Mines, Melbourne.
Department of Mines, Sydney.
Geological Survey of Canada.
Geological Survey of India.
Geological Survey of New South Wales.
Mining Society of Nova Scotia.
Mysore Geological Department.
Royal Society of New South Wales.

United States.

American Association for the Advancement of Science.
American Foundrymen's Association.
American Institute of Mining Engineers.
American Iron and Steel Association.
American Society of Civil Engineers.
American Society of Mechanical Engineers.
Department of Labour.
Engineers' Society of Western Pennsylvania.
Franklin Institute.
Massachusetts Institute of Technology.
New York Academy of Sciences.
Ordnance Office, War Department.
School of Mines, Columbia College, New York.
Smithsonian Institution.
United States Geological Survey.

Austria.

K. K. geologische Reichsanstalt.
Oesterr. Ingenieur- und Architekten-Verein.

Belgium.

Association des Ingénieurs sortis de l'École des Mines de Liége.
Ministère de l'Intérieur.

COLONIAL AND FOREIGN—*continued.*

France.

Comité des Forges.
Société d'Encouragement pour l'Industrie Nationale.
Société de l'Industrie Minérale.
Société des Anciens Élèves des Écoles Nationales d'Arts et Métiers.
Société des Ingénieurs Civils.
Société Scientifique Industrielle de Marseille.

Denmark.

Tekniske Foreningen.

Germany.

Königliche Bergakademie in Freiberg.
Königlichen Materialprüfungsamt.
Verein Deutscher Eisenhüttenleute. (Journal "Stahl und Eisen.")
Verein Deutscher Ingenieure.

Italy.

Reale Accademia dei Lincei.

Sweden.

Geological Institution of the University of Upsala.
Jernkontoret.

JOURNALS.

The following periodicals have been presented by their respective Editors:—

UNITED KINGDOM.

"Automobile Club Journal."
"British Fire Prevention Committee."
"Cassier's Magazine."
"Coal and Iron."
"Colliery Guardian."
"Concrete."
"Contract Journal."
"Electrical Engineer."
"Electrician."
"Engineer."
"Engineer and Iron Trades Advertiser."
"Engineering."
"Engineering Press Monthly Index Review."
"Engineering Review."
"Engineering Times."
"Hardware Trade Journal."
"Hardwareman."
"Horological Journal."
"Iron and Coal Trades Review."
"Iron and Steel Trades Journal."
"Iron Trade Circular."
"Ironmonger."
"Kynoch Journal."
"Machinery Market."
"Marine Engineer."
"Mechanical Engineer."
"Navy League Journal."
"Page's Weekly."
"Petroleum Review."
"Phillips' Monthly Register."
"Plumber and Decorator."
"Practical Engineer."
"Quarry."
"Railway Times."
"Railway World."
"Science and Art of Mining."
"Shipping World."
"South African Engineering."
"Statist."
"Syren."
"Tool and Machinery Register."
"Vulcan."

COLONIAL AND FOREIGN.

Colonial.

"Canadian Mining Review."
"Indian Engineering."
"Indian Textile Journal."
"New Zealand Mines Record."

United States.

"American Journal of Science."
"American Machinist."
"Bradstreets."
"Electrochemical and Metallurgical Industry."
"Engineering and Mining Journal."
"Engineering Magazine."
"Engineering News."
"Industrial World."
"Iron Age."
"Iron Trade Review."
"Machinery."
"Mines and Minerals."
"Mining World."
"Railroad Gazette.

COLONIAL AND FOREIGN—*continued.*

Austria.

"Oesterr. Zeitschrift für Berg- und Hüttenwesen."

Belgium.

"Association de la Presse Technique."
"Bulletin de l'Union des Charbonnages de Liége."
"Moniteur des Intérêts Matériels."
"Revue Universelle des Mines."

France.

"Annales des Mines."
"L'Echo des Mines."
"La Revue Mineralurgique."
"Le Génie Civil."
"Le Mois Scientifique et Industriel."
"Portefeuille Économique."

Germany.

"Annalen für Gewerbe und Bauwesen."
"Chemiker Zeitung."
"Eisen-Zeitung."
"Glückauf."
"Metallurgie."
"Verein Deutscher Eisen- und Stahl-Industrieller."
"Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate."
"Zeitschrift für praktische Geologie."
"Zeitschrift für Werkzeugmaschinen und Werkzeuge."
"Zentralblatt für Eisenhüttenwesen."

Italy.

"L'Industria."
"Rassegna Mineraria."

Peru.

"Cuerpo de Ingenieros de Minas."

Spain.

"Revista Minera."

Sweden

"Teknisk Tidskrift."
"Svensk Export."

SECTION II.

NOTES ON THE PROGRESS OF THE HOME AND FOREIGN IRON AND STEEL INDUSTRIES.

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In the preparation of these Notes the Editor has been assisted by E. J. BALL, Ph.D., Assoc. R.S.M., and by L. P. SIDNEY.

IRON ORES.

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I.—*OCCURRENCE AND COMPOSITION.*

Formation of Ore Deposits.—The practical importance of geology in the study of ore deposits is urged by J. D. Irving.*

O. Stutzer † discusses the origin of iron ore deposits, and gives a scheme of classification for such deposits. A. Schierl ‡ also gives a classification of ore deposits, and summarises the theories of the origin of veins.

H. Potonié § discusses the formation of iron ores by the agency of organisms.

J. W. Gregory || discusses the formation of ore deposits and their distribution in depth. The future metal supply of the world will, he believes, be derived from ores deposited by secondary processes in lodes or masses. He discusses the lateral secretion theory and the derivation of iron ores from igneous rocks, together with the mechanics of stratigraphical deposition, and of primary and secondary surface enrichment.

L. Cayeux ¶ discusses the structure and probable origin of the magnetic iron ore deposits of Diélette. The deposits occur in granite

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* *Yale Science Monthly*, June 1906.

† *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. liv. pp. 301-304.

‡ *Einteilung der Erzlagerstätten*, Mähr. Ostrau, 1905.

§ *Der Erz-bergbau*, 1906, pp. 448-454.

|| *Chemical News*, vol. xciv. pp. 141-143 and 154-156.

¶ *Comptes Rendus*, vol. cxlii. pp. 716-718; *Génie Civil*, vol. xlviii. p. 366.

rock at Flamanville, and microscopic examination reveals the fact that the iron ore bodies preserve a typical oolitic structure. He concludes that calcareous oolites have been directly transformed into magnetic iron ore by metamorphism at a period coeval with the formation of the granite. Alternately he suggests that the iron has been substituted for the lime at a more recent period.

L. Cayeux,* in a microscopic examination of the glauconite and limonite grains in the ferruginous mineral found at Grandpré, Ardennes, shows that the limonite has been produced by transformation of the glauconite, which originally formed the chief mineral constituent of the deposit.

Iron Ore in Austria.—F. Kretschmer † gives a mineralogical description of the magnetite of Gobitschau.

Iron Ore in Germany.—The Bavarian National Exhibition at Nuremberg (May to October 1906) contained a representative display of the mineral resources of the kingdom, which are described by O. Friz,‡ and include the iron ore deposits of the Fichtelgebirge, and the brown iron ore deposits of Sulzbach.

A. Schmidt § has prepared for the Bavarian Exhibition at Nuremberg a pamphlet describing the minerals from the abandoned mines of the Fichtelgebirge. The occurrences of iron and manganese ore, and the nickel ores of Steben and Lichtenberg, are also briefly dealt with.

A. Schmidt ‖ describes elsewhere the occurrence of iron and manganese ore in the Fichtelgebirge, Bavaria. An analysis of specular iron ore from this district yielded 95·16 per cent. of ferric oxide.

A description has been published ¶ of the iron ore deposits of the Taunus. The ores are chiefly brown iron ores containing a low percentage of manganese. The ore occurs in veins and beds in quartzite. The veins, which are the less frequent, consist of limonite with 47 to 50 per cent. of iron and 0·38 to 1·38 per cent. of manganese. The beds are associated chiefly with sericite schists, the most important bed being at the Schlossberg mine, where three beds, 6 to 12 feet thick, are mined.

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* *Comptes Rendus*, vol. cxlii. pp. 895–897.

† *Zentralblatt für Mineralogie*, 1906, pp. 304–306.

‡ *Zeitschrift für praktische Geologie*, vol. xiv. pp. 256–261.

§ *Mineralien aus den auflässigen Bergwerken des Fichtelgebirges*, 1906.

‖ *Der Erz-bergbau*, 1906, pp. 666–668.

¶ *Ibid.*, pp. 561–563, 586–588; *Zentralblatt für Eisenhüttenwesen*, vol. i. pp. 465–467.

Iron Ore in Italy.—G. Ristori* describes the limonite deposits of Monte Valerio, Monte Spinosa, and Monte Rombola (Campiglia Marittima). The deposits, which occur in Liassic limestone, do not appear to be of economic value.

Iron Ore in Norway.—The occurrence of iron ore in Mosjöen is described.† The deposit is one of the richest in Norway, the ore consisting of specular iron ore and magnetite free from titanium and chromium. The percentage of iron amounts to 61·09 per cent.

Iron Ore in Russia.—C. Monkofski ‡ discusses the geology of Krivoï Rog, with special reference to the area and extent of the crystalline schists in which the iron ore deposits occur. He gives the results of numerous borings, and criticises the conclusions of Sokoloff, that there is no data for determining the western limits of the formation. He considers that the facts observed tend to show that there are three distinct zones, the delimitation of which can be readily ascertained. Three distinct deposits of ore occur, those of Krivoï Rog itself being the most important.

Iron Ore in Spain.—F. Fircks, § in a geological description of some ore deposits in the province of Almeria in Spain, deals at length with the occurrence of spathic iron ore in the Sierra de Almagrera, of manganiferous iron ore at Herrerias, and of iron ore at the Serena mines. He gives a geological map of the province and sections of the mines at Serena. The following deposits are dealt with: 1. The Sierra de Bédar and Coscojares lead, copper, and iron ore deposits. 2. The Sierra de Almagrera lodes of lead ore rich in silver, and deposits of spathic iron ore. 3. The Herrerias silver and iron ores. After describing the general geological conditions the author details the deposits. The Sierra de Bédar and Coscojares deposits resemble one another in an astonishing manner; only in the Coscojares the workings have not been so important as in the Sierra de Bédar. The author devotes special attention to the Serena and Tres Amigos iron mines. As ores of economic value only the various kinds of brown hæmatite occur. A very rich pulverulent iron ore with a low percentage of silica is the most usual, and in certain places a lumpy ore with a high percentage of silica occurs. Wherever the lumpy ore occurs there is no marked limit between the profitable ore and the worthless rock, but the rich pulverulent ore appears in well-defined limits. The ore is carried by a wire ropeway and shipped at the port of Garucha. From 1893 to 1903 the yearly production of the mine was about 100,000 tons. Average analyses showed the lumpy ore to contain 48 per cent. of iron, and the pulverulent ore 58 per cent. The percentages of sulphur and phosphorus are within the limits prescribed for the best ores.

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* *Atti della Società toscana di Scienze Naturali, Pisa*, vol. xx. pp. 60–75.

† *Zentralblatt für Eisenhüttenwesen*, vol. i. p. 394.

‡ *Revue Universelle des Mines*, vol. xiii. pp. 72–105.

§ *Zeitschrift für praktische Geologie*, vol. xiv. pp. 142–150, 233–236.

C. H. M. Trayner * gives an account of the ore supplies of Asturias. The ores are chiefly derived from beds of Devonian age, and contain on an average 20 per cent. of silica, 49 per cent. of iron, 0·21 per cent of sulphur, 0·41 per cent. of phosphorus, and 4·5 per cent. of alumina They are obtained from three districts, the Mieres mines at Santo Firme—where the beds measure 3 feet 6 inches, 5 feet, and 8 feet 3 inches in thickness—Teberga, and Pravia. Ores also occur in Somiedo and at Bayo. The beds in all these localities are now being worked. A thin bed of hæmatite, occurring in the carboniferous beds, is also worked by the Mieres Company. It contains 64 per cent. of iron. A carbonate intermixed with black shale has also been discovered, but it occurs in a mountainous region where great practical difficulties exist in the way of transport to ports convenient for shipment.

Iron Ore in Sweden.—A. Dellwik † describes the Gellivare iron ore deposits. The ore is partly magnetite and partly red hæmatite. Numerous analyses are given showing that the proportion of iron in the ore varies from 62·69 to 68·87 per cent., the phosphorus from 0·013 to 1·282 per cent., and the sulphur from 0·03 to 0·16 per cent. The manganous oxide varies from 0·07 to 0·23 per cent., and the titanic acid from 0·05 to 0·82 per cent. The annual production is about 900,000 tons.

The Gellivare iron ore deposits,‡ and those at Kiiruna,§ are described by O. Stutzer. He gives a bibliography of the subject. The Gellivare mines have already produced 1½ million tons of ore. The ore, like that of Kiiruna, is composed of magnetite and apatite. The ore of Gellivare is chiefly granular, and can be broken up in the hand, but the Kiiruna ore is firm and hard. After a few remarks on the character of the iron ore deposits, the theories of their origin are reviewed. Swedish scientists are inclined towards the sedimentation theory, but the author concludes that the Gellivare iron ore deposit is a metamorphosed deposit of epigenetic origin, and as at Kiirunavaara, a magmatic segregation with considerable lateral secretion. The author submits evidence in support of the epigenetic magmatic origin of the Kiiruna iron ore deposits.

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* *Iron and Coal Trades Review*, vol. lxxiii. pp. 1177–1179.

† *Jernkontorets Annaler*, vol. lx. pp. 259–320.

‡ *Zeitschrift für praktische Geologie*, vol. xiv. p. 137. § *Ibid.*, p. 140.

F. König * describes some of the iron ore and manganese ore mines of western Central Sweden.

An abstract is given of the views expressed by G. Henriksen † as to the mode of origin of Swedish iron ore deposits. In many places the formation is thought to have been directly due to changes in eruptive masses effected by pressure. In some it would seem as if the quartz has been wholly squeezed out. In Dunderland this pressure action is general, and this leads to the belief that the ore will be found to extend to a very considerable depth.

Iron Ore in India.—E. Vredenburg ‡ notes the occurrence of iron ore in Panna State. The ore is of two kinds—lateritic, consisting of hæmatitic nodules and laterite, and a ferruginous breccia.

Reports on iron ore properties in the Mayurbhanj State and in the Raipur district in the province of Bengal have been prepared by W. Selkirk and by C. P. Perin and C. M. Weld § for the Tata Iron and Steel Company, to be formed for the purpose of erecting iron and steel works in India. The reports show that the fields contain a very large supply of high-grade ore. At Mayurbhanj over seven million tons of ore have been proved to exist, the ore containing 60·5 to 63·2 per cent. of iron, 0·012 to 0·036 per cent. of sulphur, and 0·059 to 0·135 per cent. of phosphorus.

W. F. Smeeth ‖ describes the occurrence of iron and manganese ores in Mysore. The quality of the manganese ore in the Shankargudda range appears to be decidedly good.

E. W. Wetherell ¶ describes the laterite of Mysore. Although rich in iron, no recorded attempt at iron smelting appears to have been made, although several fragments of slag have been found on one of the laterite hills.

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* *Zeitschrift des Oesterreichischen Ingenieur- und Architekten-Vereines*, vol. lviii. p. 386.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. p. 168.

‡ *Records of the Geological Survey of India*, vol. xxxiii. p. 313.

§ Copies of these reports have been presented to the Institute Library.

‖ *Records of the Mysore Geological Department*, vol. v. pp. 17, 28, 34, 54, 61.

¶ *Memoirs of the Mysore Geological Department*, vol. iii. pp. 1-27.

Iron Ore in Canada.—In a report on the Chibougamau mining region in the northern part of the province of Quebec, A. P. Low [*] states that no deposits of iron ore of size sufficient to render them of economic value have, up to the present, been discovered in the region under consideration. Small deposits of iron ore have been found in the gabbro rocks, and many small veins of beautifully crystallised specular iron ore in conglomerate. The occurrence of large blocks of magnetite-hæmatite ores with bands of red jasper is the most promising indication of the presence of valuable iron ores in the region.

W. H. Collins [†] describes the occurrence of iron ore in the Archæan region north of Lake Superior. Limonite was observed filling small veins in granite near Rossport; and magnetite occurs in biotite schist on Caribou lake. Magnetite also occurs as thin layers in black schist near Schreiber, and as magnetic sands at points distributed over the whole area.

The iron deposit at the Helen iron mine, Michipicoten, Ontario, is described by A. P. Coleman.[‡]

W. F. C. Parsons [§] gives an account of prospecting operations for iron ore carried out in the Torbrook district, Nova Scotia. The area prospected is about 5 miles long and about 1½ miles wide, and the veins run nearly east and west. The north section contains the outcrop of three veins, and the south section the outcrop of two veins, the north and south outcrops running nearly parallel to each other. Several shafts have been sunk and three bore-holes put down. A representative sample at the Leckie mine yielded 52 per cent. of iron, 1·15 per cent. of phosphorus, 0·02 per cent. of sulphur, 0·10 per cent. of manganese, 13·5 per cent. insoluble matter, 0·30 per cent. of magnesia, and 2·5 per cent. of lime.

Iron Ore in Western Australia.—A sample of laterite iron ore from Comet Vale, North Coolgardie, examined by the Geological Survey of Western Australia, [‖] proved of great interest on account of the occurrence in it of a notable proportion of chromium, mostly in the form of a hydrate.

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[*] *Geological Survey of Canada*, Report No. 923, p. 57.

[†] *Summary Report of the Geological Survey Department of Canada*, Ottawa, 1906, p. 81.

[‡] *Economic Geology*, June 1906.

[§] *Canadian Mining Review*, vol. xxvi. pp. 152–153.

[‖] *Annual Progress Report*, Perth, 1906.

Iron Ore in British Central Africa.—Analyses have been published[*] of magnetite with 68·52 per cent. of iron and 0·26 per cent. of phosphorus, and of titaniferous iron ore from Central Africa.

Iron Ore in Asia Minor.—A detailed account of the mineral resources of Asia Minor is given by C. Schmeisser[†] with a map. Chrome iron ore is of chief importance, some 40,000 tons being exported annually. Brussa ores cost, at the coast, 50s. a ton, and Makry ores about 37s. a ton. Few deposits of iron proper are being mined.

Iron Ore in Turkestan.—J. W. Muschketoff[‡] has published a volume of 348 pages with 11 plates, 106 illustrations, and a map, describing, in Russian, the geology of Turkestan, based on observations made in 1874 to 1880. It contains descriptions of the deposits of iron ore, manganese ore, coal, graphite, and petroleum.

Iron Ore in Siberia.—The occurrence of vast deposits of iron ore, consisting mostly of brown hæmatite and of spherosiderites and magnetites, is recorded.[§] The deposits occur, amongst other places, at Telbece, in the Altaï, at Minoussinks, at Abakansk, at Irkutsk, and in the Trans Baikal. Deposits of manganese ore also occur on the Khirghis Steppes.

Iron Ore in Costa Rica.—F. C. Nicholas[‖] reports an immense deposit of iron sand which represent erosions from the mountains of the Atlantic side of the republic, where, judging from the accumulation, there must have been a period of erosion of extraordinary activity.

Iron Ore in the Argentine Republic.—Guillermo Bodenbender[¶] has published an account of the economic geology of the Sierra de Cordoba. He gives a geological map and thirty views. The magnetite beds and tungsten ore veins are described.

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[*] *Bulletin of the Imperial Institute*, vol. iv. p. 112.

[†] *Zeitschrift für praktische Geologie*, vol. xiv. pp. 186–196.

[‡] St. Petersburg, 1906.

[§] *Revue Universelle des Mines*, vol. xii. pp. 203–206.

[‖] *Mining World*, vol. xxiv. p. 723.

[¶] *Anales del Ministero de Agricoltura de la Republic Argentina*, vol. i., 150 pages.

Iron Ore at Lake Superior.—A. Oppel[*] gives an illustrated account of the great iron ore deposits of the Lake Superior region; and the Northern iron ore fields of America are described by M. P. Youngs.[†]

The iron concretions of the Redbank Sands are discussed by O. W. Willcox.[‡]

Iron Ore in Alabama.—A description has been published[§] of the limonite deposits of the Coosa Valley region. The ore contains 51 per cent. of iron, 9 per cent. of silica, 3·75 per cent. of alumina, 0·75 per cent. of lime, 0·40 per cent. of phosphorus, and 0·10 per cent. of sulphur.

Iron Ore in Colorado.—H. Baxter[||] discusses the probability of finding iron ore in Colorado.

Iron Ore in Kentucky.—W. C. Phalen[¶] describes the origin and occurrence of the iron ores of the Hanging Rock region of North-eastern Kentucky. The ores are chiefly carbonates, but they have been altered near the outcrop to limonite.

Iron Ore in New York.—J. H. Granbery[**] describes the magnetite deposits at Mineville, New York. They occur in a valley, are associated for the most part with gabbro, and are titaniferous. Molybdenite, titanite, and other industrial minerals also occur in the district. The famous magnetite deposits worked by Witherbee, Sherman & Co. are situated in the eastern portion of Essex county. The different theories which have been put forward to account for their occurrence are briefly reviewed. The magnetite occurs in well-defined crystals, and on account of this property breaks up readily. The portions of the ore body now worked are the Harmony mines, the Old Bed mines, and the Smith mine. Since operations were commenced on a commercial scale, in 1849, 15,000,000 tons of ore have been produced. The ore from the first-named mines averages

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[*] *Der Erz-bergbau*, 1906, pp. 700–707.

[†] *Mining World*, vol. xxiv. pp. 300–301.

[‡] *Journal of Geology*, vol. xiv. pp. 243–252.

[§] *Report of the Alabama Geological Survey*; abstract in *Mining World*, vol. xxv. p. 211.

[||] *Mining Reporter*, July 10, 1906.

[¶] *Economic Geology*, July-August 1906.

[**] *Engineering and Mining Journal*, vol. lxxxi. pp. 889–892, 986–989.

62 to 64 per cent. of iron, and 12 per cent. of phosphorus. Mining is carried on by shaft work and stoping. The highest room in the Old Bed workings is 240 feet high, and the roof area supported between pillars is 280 by 60 feet. It is estimated that 800,000 tons of ore are left in the pillars of this mine alone, some of the individual pillars containing 50,000 tons of ore.

A description is given * of the reopening of the historic Forest of Dean iron ore mine, Orange County, New York, which was discovered in 1756. The ore is a magnetite, and has furnished 1,000,000 tons of ore during the period of its working, from 1862 to 1894. It was reopened in October 1905 by the Hudson Iron Company, which has purchased land adjacent to the property, with vein outcrops extending nearly half a mile, and estimated as representing over a million tons, and a further tract of 1050 acres in which drills have shown the existence of a vein of Bessemer ore.

R. B. Brinsmade † describes various deposits of hæmatite in the State of New York.

Manganese Ore in Bosnia.—F. Katzer ‡ describes the manganese ore district of Cevljanovic in Bosnia. This district supplies all the manganese ore used in Austria. The deposit forms a syngenetic member of the marine Jurassic beds enclosing it.

J. H. L. Vogt § discusses the distribution and economic importance of wad manganese ore deposits.

Manganese Ore in Algeria.—The report of the British Vice-Consul at Bône, A. de la Croix, ‖ contains an account of the mineral resources of that locality. In the districts of Soukahras and Tébessa, manganese peroxide, containing 65 per cent. of metal, has been found

Manganese Ore in India.—R. Stokes ¶ describes the development of the manganese mines in the Madras Presidency, and gives illustrations of the Kodur and Grabnam deposits in the Vizianagram district, Madras.

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* *Iron Age*, vol. lxxvii. pp. 1972–1975.

† *Engineering and Mining Journal*, vol. lxxxii. pp. 493–495.

‡ *Berg- und Hüttenmännisches Jahrbuch der k. k. Montanistischen Hochschulen*, vol. liv. pp. 203–244.

§ *Zeitschrift für praktische Geologie*, vol. xiv. pp. 217–232.

‖ *Foreign Office, Annual Series*, No. 3712.

¶ *Mining World*, vol. xxiv. p. 719.

T. H. Holland * summarises the reports by L. L. Fermor on the manganese ore deposits of Jabalpur, Ganjam, Jhabua, the Panch Mahals, Nárukot, and Satára, and by J. M. Maclaren and R. B. Foote on those of Belgaum and Dhárwár, and of the Sandur State respectively. The examination of the deposits in the Vizagapatam district has enabled a theory as to the origin of manganese-silicate rocks to be formulated. Some of the deposits were of special interest, as they resulted in the discovery of two new minerals—a blue amphibole, and a manganate of barium, iron and manganese corresponding to the formula $(Ba_3Mn_3Fe_2^{iv})_2(MnO_5)_8$.

L. L. Fermor † gives some notes on the petrology and manganese ore deposits of the Sausar Tahsil, Chhindwára district, Central Provinces, in which he puts on record petrological descriptions of certain types of rocks, chiefly of the metamorphic and crystalline series, and gives an account of the eleven manganese ore deposits known to occur in this area. Several of them are of economic importance. Six plates of rock photomicrographs accompany the paper.

L. L. Fermor ‡ records the occurrence of manganite in the Sandur Hills and in the Chhindwára district, and Gwalior. In the Sandur Hills the manganese ores form an outcrop of huge boulders of psilomelane extending about 450 feet along the strike. It is in association with the occurrence of the psilomelane that manganite has been found. The mineralogical and petrological characteristics of the mineral are described.

Manganese Ore in Borneo.—According to the report of W. G. Darby,§ manganese ore deposits in Murudu Bay, British North Borneo, are being worked, and arrangements are being perfected for shipments of the ore on a large scale.

Manganese Ore in Brazil.—The mining of manganese in Brazil is described by A. de Belmont.||

Cobalt and Nickel Ores.—W. G. Miller ¶ describes the further discoveries of rich deposits of cobalt-nickel arsenides at Cobalt,

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* *Records of the Geological Survey of India*, vol. xxxiii. pp. 94–100.

† *Ibid.*, pp. 159–220.

‡ *Ibid.*, pp. 229–232.

§ *Foreign Office, Annual Series*, No. 3715.

|| *Mining World*, vol. xxiv. p. 522.

¶ *Report of the Bureau of Mines*, Ontario, 1905, Part II.

Ontario. The ores occupy narrow vertical fissures cut through a series of slightly inclined metamorphosed Huronian rocks. Analyses are given of the composition of the ores. The deposits are worked by means of open cuts, although a shaft has been sunk at La Rose. The productive area is roughly rectangular, being about 2½ miles long and somewhat less wide.

C. W. Dickson * discusses the genetic relations of some nickel copper ores, with specific reference to those of St. Stephen, New Brunswick, and of Sohland, Saxony.

A. E. Barlow † and D. H. Browne ‡ give notes on the origin of the nickel ore deposits of Sudbury, Canada.

A. E. Barlow § deals with the nickel ore deposits of Sudbury, Ontario. He summarises the reports and memoirs which have already appeared respecting these deposits, and gives abstracts of papers communicated by various authors to technical and scientific bodies. He then deals with the progress of the development of the nickel and nickel copper resources of the province, giving an account of the operations of the principal mining companies engaged in working the deposits. The general physical features of the Sudbury mining district are then discussed, and the geology and mineralogical and petrological characteristics described at length, analyses being given of the chief minerals found and of the ores from the leading mines. The origin of the deposits is discussed, together with the methods employed for the magnetic separation of pyrrhotite. Mineralogically nickel ores are classified into eight classes: (1) Sulphides, (2) arsenides and sulpharsenides, (3) sulph-antimonides, (4) sulpho-bismuthides, (5) tellurides, (6) silicates, (7) oxides and salts, and (8) carbonates. The Sudbury deposits are then compared with those of Norway and Sweden, which they closely resemble. An account is given of the occurrence of nickel in Scandinavia and in other parts of Europe, and in the United States and New Caledonia. Comparative tables of the analysis of ores from each of these localities are given, after which the author deals with the metallurgy of nickel and describes the operations of roasting the ores and the subsequent treatment of the matte, concluding with a short account of the industrial uses of nickel and its influence in alloys of steel.

J. A. Macdonald ‖ describes the occurrence and development of

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* *Canadian Mining Review*, vol. xxvi. pp. 144–151.

† *Economic Geology*, vol. i. pp. 454–466. ‡ *Ibid.*, pp. 467–475.

§ *Annual Report of the Geological Survey of Canada*, vol. xiv. pp. 5–232 H.

‖ *Engineering Magazine*, vol. xxxi. pp. 406–416.

cobalt ore deposits in Ontario. The ore bodies which carry silver, nickel, and arsenic in addition to cobalt are found within a short distance from the shore of Lake Temiskaming, about half a mile from Cobalt station. The outcrops, which are pink, are apt, on superficial inspection, to be mistaken for red oxide of iron. The veins are narrow (10 to 12 inches), and the ore contains 11·27 to 15·6 per cent. of cobalt, and 3·78 to 7 per cent. of nickel. The cobalt-silver veins mostly occur in the Lower Huronian formation.

Tungsten Ore.—J. H. Collins[*] refers to the occurrence of wolframite in the west of England. The estimated production from the East Pool mine in 1905 was 136 tons, valued at £3350.

H. R. Wagenen[†] describes the occurrence of tungsten ores in Colorado. They occur as hubnerite, associated with pale green fluorite, in San Juan County. In Boulder County they occur as wolframite, scattered in quartz, which has to be crushed before the wolfram can be recovered. The methods employed in these two districts are described, and a bibliography of the occurrence and properties of tungsten is given.

R. S. Baverstock[‡] describes a California scheelite deposit.

Recent Researches on Meteorites.—A. Brezina[§] and E. Cohen have published further instalments of their great work on the structure and composition of meteoric irons elucidated by photographs of etched surfaces.

A summary of recent progress in the study of meteorites is given by A. Hutchinson.[||] He devotes attention chiefly to the work of F. Rinne,[¶] in which the structure and composition of meteoric iron are compared with those of iron and steel, the subject being treated from the point of view of physical chemistry and the phase-rule. In meteorites far-reaching transformation may take place long after the alloy composing them has become solid. Thus nickel-iron is the equivalent of ferrite, cohenite of cementite, schreibersite of Fe_3P, and troilite of FeS ; and just as martensite may break up on cooling into ferrite and pearlite, so also in nickel-iron similar changes may occur.

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[*] *Engineering and Mining Journal*, vol. lxxxi. pp. 1225–1226.

[†] *Bulletin of the Colorado School of Mines*, January 1906 ; *Mining Magazine*, vol. xiii. pp. 327–329.

[‡] *Mining World*, vol. xxiv. pp. 414–415.

[§] Parts IV. and V., Stuttgart, 1906 (price 40s.).

[||] *Annual Reports on the Progress of Chemistry, issued by the Chemical Society*, vol. ii. pp. 292–294.

[¶] *Geologisches Centralblatt*, vol. viii. p. 499.

C. Klein [*] has published a treatise on meteorites, based on the investigations of material in the Berlin University collection.

F. Berwerth [†] adduces evidence to show that the great group of crystalline granular meteoric irons are octahedral iron recrystallised in consequence of heating in a solid state. He terms these recrystallised irons the group of metabolites. He gives the results of experiments made with a small plate of the Toluca iron to ascertain the accuracy of his view that the great group of crystalline-granular meteoric irons are octahedral irons recrystallised in consequence of heating in a solid condition. The plate, 5 millimetres in thickness, was embedded in powdered charcoal in a graphite crucible and heated for seven hours at a temperature of about 950° C. The results obtained lead the author to propose to term the recrystallised meteoric irons "the group of the metabolites." With the increasing knowledge of the physical characters of the artificial iron-nickel alloys, fresh light will be thrown on the various forms of iron metabolites.

An account is given of a number of historic meteorites.[‡]

O. C. Farrington [§] gives an analysis of a magnetic oxide of iron from Coon Mountain, Arizona, locally known as "iron shale." It has been thought that the oxidation that produces the shale took place during the fall of the Cañon Diablo meteoric iron, but the author considers that the oxidation occurred subsequently, and was so gradual that the production of the shale can be explained only by assuming that the fall took place many years ago.

D. M. Barringer [||] and B. C. Tilghman have discovered that the crater of Coon Mountain in Northern Arizona, twelve miles south-east of Cañon Diablo station, is an impact crater and not a crater produced by a steam explosion. The authors have proved that the large crater known as Coon Mountain is the result of a collision with the earth of a very large meteorite or possibly a small asteroid, fragments of which are well known to the scientific world by the name of the Cañon Diablo siderites. These views are discussed by L. Fletcher.[¶] J. W. Mallet [**] describes the meteoric stone weighing

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[*] *Studien über Meteoriten*, Berlin, 1906, price 7s.

[†] *Sitzungsberichte der kaiserlichen Akademie der Wissenschaften*, Vienna, vol. cxiv. pp. 1–14.

[‡] *Canadian Mining Review*, vol. xxvii. pp. 38-40.

[§] *American Journal of Science*, vol. xxii. pp. 303–309.

[||] *Proceedings of the Academy of Natural Sciences of Philadelphia*, December 5, 1905.

[¶] *Nature*, vol. lxxiv. pp. 490–492.

[**] *American Journal of Science*, vol. xxi. pp. 347–355.

2789 grammes found at Coon Mountain, Arizona, in June 1905, a meteoritic fall having been observed in this locality about January 15, 1904. The structure is indistinctly chrondritic and the mineralogical composition is as follows: Enstatite, 44·73; olivine, 33·48; maskelynite (?), 6·87; nickel-iron, 8·63; iron-rust, 3·03; schreibersite, 0·76; pyrrhotite, 2·14; chromite, 0·08 per cent. The nickel-iron has the following composition:—

Fe.	Ni.	Co.	Cu.	Sn.	Mn.	C.	Total.
88·81	10·72	0·15	trace	0·01	trace	trace	99·69

G. P. Merrill* and W. Tassin describe a meteorite which was observed to fall at Modoc, in Scott County, Kansas, on September 2, 1905. Several stones and some fragments were picked up over an area of two by seven miles. The structure is chrondritic, and the material is traversed by thread-like black veins. Analyses are given.

A description of the various meteorites which fell at Amana, Iowa, in 1875 is given by G. D. Hinrichs.† Two plates accompanying the description show photographic reproductions of the meteorites, together with the names of the museums in which they are now to be found.

K. S. Howard‡ describes the Estacado aerolite from Texas. It is amongst the largest known. Analysis by J. M. Davison showed that 16·41 per cent. is metallic, the metallic portion containing 89·45 per cent. of iron, 9·99 per cent. of nickel, and 0·56 per cent. of cobalt.

F. Berwerth§ describes the meteoric iron of Kodaikanal, Palm Hills, Madras. This meteoric iron is of special interest in that, on etching, it exhibits a crystalline mass of large octahedral iron grains between which globular masses of silicates of unusual character have separated out. The general structure of the iron is thus of a porphyritic type. The ratio between the iron mass and the silicates is approximately 10 to 1. Careful examination has shown that the silicate segregations are of two kinds, a spherolithic ground mass and glassy globules. The former consists of weinbergite, diopside, bronzite, apatite, and chromite, and the latter of a glassy magma containing suspended bronzite and chromite. The new silicate compound to which the author gives the name of weinbergerite is found by analysis to have the composition represented by the formula $NaAlSiO_4 + 3FeSiO_3$.

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* *American Journal of Science*, vol. xxi. pp. 356–360.

† *Das Weltall*, September 15, 1906; *Nature*, vol. lxxiv. p. 575.

‡ *American Journal of Science*, vol. xxii. pp. 55–60.

§ *Tschermaks Mineralogische Mitteilungen*, vol. xxv. pp. 179–198.

II.—*IRON ORE MINING*

Underground Temperature.—J. Königsberger[*] discusses the influence, on the geothermal gradient, of hills and valleys, position of strata, flowing water, and heat-producing intercalations.

W. Branco[†] discusses H. Höfer's attempt to explain the high thermal gradient in the bore-hole at Neuffen in Bohemia.

Deep Boring.—The various methods of deep boring are described by E. Wenzel.[‡]

W. Halder[§] describes modern deep-boring practice in Europe.

A. Habets[||] describes the boring appliances shown at the Liége Exhibition. They include the Wolski hydraulic ram apparatus, used with great success in Galicia and in the Caucasus, and the François percussion drill. The Wolski percussion drill is also described.

C. Rauscher[¶] describes the Craelius diamond boring machine for exploratory work in mines.

It is noted that valuable information has been afforded by horizontal diamond-borings at various levels at the Gilberg iron mine, Siegen. In three months thirteen bore-holes were put in, with a total length of 700 metres. The speed of boring was, on an average, 3·8 metres per eight hours, with a bore-hole diameter of 40 millimetres, and a core diameter of 22 millimetres.[**]

A description has appeared[††] of a new method of boring, designed by T. Matthews. The system is the percussion method in conjunction with a rotating bar. The bar in which the boring tools are mounted is suspended by a wire rope and the stroke is given to the bar, so that the cutters strike the bottom of the bore-hole about thirty times in a minute. A depth of 600 feet can be bored with the No. 2 machine, the total weight of which is under 5 tons.

J. Baszanger[‡‡] describes the appearance and properties of the carbonado or black diamond found in Bahia, Brazil. Stones of considerable size have been found, among others some of 3078, 1700, and 1100 carats.

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[*] *Eclogæ Geologicæ Helvetiæ*, vol. ix. pp. 133–144.

[†] *Zeitschrift der deutschen geologischen Gesellschaft*, vol. lv. pp. 174–182.

[‡] *Organ des Verein der Bohrtechniker*, vol. xiii. pp. 1–3, 16–17, 28–29.

[§] *Mining Magazine*, vol. xiii. pp. 33–36.

[||] *Revue Universelle des Mines*, vol. xii. pp. 209–226.

[¶] *Montan Zeitung*, vol. xiii. p. 216.

[**] *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. liv. pp. 276–277.

[††] *Engineer*, vol. ci. p. 357.

[‡‡] *Engineering and Mining Journal*, vol. lxxxi. p. 857.

F. Freise [*] observes that experience has shown that most bore-holes pass out of plumb; and their control from this point of view while being put down is therefore of the greatest importance. It is also of extreme importance when borings are being made in connection with the freezing method of shaft sinking, and the author therefore passes in review the various ways in which the necessary supervision of the bore-master can be effected. The methods are subsequently compared.

F. Freise [†] deals with the development of the stratameter. The necessity for such an instrument in connection with bore-hole practice soon made itself felt, and he traces its gradual development, commencing with the experiments made by Kind near Forbach in Lorraine in 1888, and describing the apparatus of this type subsequently devised.

Stratameters for surveying bore-holes are described by E. Wenzel [‡] and by F. Freise.[§]

Shaft-Sinking.—F. Wanjura [‖] describes the sinking of shafts in Michigan by means of Friestedt's method with iron beams.

S. H. Dunshee [¶] deals with shaft-sinking in Montana.

R. B. Brinsmade [**] describes the method of sinking shafts at Tombstone and Bisbee in Arizona, where the flow of water was 3000 and 2000 gallons per minute respectively.

Concrete lining for mine shafts is described by C. Henrich,[††] who gives a comparison of costs of concrete lining and timbering.

Inclined Shafts.—Some considerations in the equipment of inclined shafts are given by F. N. Hambly.[‡‡]

Tunnels.—The completion of the Simplon Tunnel, 12¼ miles in length, at a cost of £3,100,000, and at an average rate of 2 miles a year, has induced Lewis M. Haupt* to publish some comparative notes on other great tunnels. The Hoosac Tunnel, Massachusetts, 5 miles in length, was begun in 1854 and completed in 1876, with an average progress of 5·5 feet per day. The Mont Cenis Tunnel, 8 miles in length, was begun in 1857 and completed in 1871, with an average progress of 8 feet per day. The Sutro Tunnel, Nevada, 4 miles in length, was begun in 1869 and completed in 1878, with an average progress of 10·24 feet per day. The St. Gothard Tunnel (1872–1881), 9¼ miles in length, was driven at the rate of 14·6 feet per day. The Arlberg Tunnel (1880–1884), 6·38 miles in length, was driven at the rate of 27·8 feet per day.

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[*] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 175–177, 187–190, 206–209, 219–221, and 230–231, with fifteen illustrations.

[†] *Ibid.*, pp. 527–530, 545–549, and 560–563, with one plate.

[‡] *Organ des Verein der Bohrtechniker*, vol. xiii. pp. 109–110.

[§] *Ibid.*, pp. 133–135, 157–160, 171–173.

[‖] *Bihang till Jernkontorets Annaler*, 1906, pp. 252–259.

[¶] *Mining Reporter*, September 20, 1906.

[**] *Mines and Minerals*, vol. xxvii. pp. 97–99.

[††] *Mining World*, vol. xxv. p. 91.

[‡‡] *Page's Weekly*, vol. vii. pp. 1429–1434, with four illustrations.

Detailed accounts of the construction of the Simplon Tunnel have been published by C. J. Wagner † and K. Pressel.‡ The construction of the Simplon Tunnel is also described, with many illustrations, by Pflug.§

Explosives.—The proper methods of thawing dynamite and the precautions to be observed are considered and discussed.||

W. Kelly ¶ states that at American mines frozen dynamite is thawed by placing the cartridges in a wooden box which is heated by electric wires. An alternating current of 110 volts is used.

W. H. Booth ** describes the manufacture of high explosives.

B. Hopkinson †† investigates the explosion of gaseous mixtures and the specific heat of the resulting products.

J. E. Petavel ‡‡ discusses the pressure of explosives and the methods and apparatus employed in experiments made on solid and gaseous explosives. The pressure gauge used had to be specially constructed as well as the recording manometer used in the experiments. Curves are given of the results obtained with cordite, together with a table of the rates of cooling of the products of combustion. The remarkable properties and regular effects of this explosive were confirmed by the investigation.

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* *Journal of the Franklin Institute*, vol. clxi. pp. 401–412.

† *Oesterr. Wochenschrift für d. Oeffent. Baudienst.*, June 9, 1906.

‡ *Schweizerische Bauzeitung*, May 26, 1906.

§ *Glasers Annalen für Gewerbe und Bauwesen*, vol. lviii. pp. 112–115.

|| *Engineering and Mining Journal*, vol. lxxxi. pp. 899–900.

¶ *Bihang till Jernkontorets Annaler*, 1906, pp. 296–300.

** *Cassier's Magazine*, vol. xxx. pp. 291–309, with thirteen illustrations.

†† *Proceedings of the Royal Society*, vol. lxxvii., Series A, pp. 387–413; *Engineering*, vol. lxxxi. pp. 777–778.

‡‡ *Proceedings of the Royal Society*, vol. lxxvi., Series A, pp. 492–494; *Engineering*, vol. lxxxi. pp. 429–433.

Sir A. Noble* has recalculated the specific heats and densities of cordite, M.D., and nitrocellulose.

The design and construction of magazines for explosives, and the precautions to be observed, are described.†

Compressed Air in Mines.—A supplement on modern air compressors, covering twenty folio pages with seventy-three illustrations, is published.‡ It gives an excellent review of the great strides made during the last fifteen years in the use of compressed air. The development of the use of compressed air as a means for transmitting power appears the more remarkable when it is remembered that during the same period the use of electricity for that purpose has grown enormously.

F. Richards § discusses the use of compressed air in rock drills, and deals with the electric rock drill, which has proved of great efficiency in actual working.

P. Bernstein ‖ gives an account of the use of hydraulic air compression plant in mines. He gives details of the first experimental plant of this kind in Germany, at Dillingen on the Saar, and of several plants in Canada.

The Sentinel air compressor is described and illustrated.¶

The relative merits of electricity and compressed air for mine operations are discussed by E. F. Schaefer.**

In a treatise on the utilisation of water power, E. Mattern †† gives much information regarding power transmission.

Rock-Drills.—A detailed description is given ‡‡ of some interesting models of rock-drilling and boring machinery that have been added to the cases devoted to this branch of mechanics at the Victoria and Albert Museum.

The subject of rock-drilling is exhaustively dealt with by W. A. T. Davies.§§ He shows that in hard crystalline and homogeneous rocks the use of percussive rock-drills is attended by the greatest economy.

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* *Proceedings of the Royal Society*, vol. lxxvi., Series A, pp. 512-514.

† *Iron and Coal Trades Review*, vol. lxxiii. pp. 1013–1014.

‡ *Engineer*, Supplement, June 15, 1906, 20 pages.

§ *Engineering News*, vol. lvi. pp. 83–84.

‖ *Glückauf*, vol. xlii. pp. 933–943.

¶ *Iron and Steel Trades Journal*, vol. lxxviii. pp. 10–11, with four illustrations.

** *Mining World*, vol. xxiii. pp. 718–719.

†† *Die Ausnutzung der Wasserkräfte*, 8vo, pp. 260, with 66 illustrations. Leipzig: W. Engelmann, 1906, price 7s.

‡‡ *Engineer*, vol. cii. pp. 217–218.

§§ *Transactions of the Australasian Institute of Mining Engineers*, vol. xi. pp. 151–163.

The "Little Hustler" variable electric drill is described and illustrated.* It can be adjusted to three speeds, according to the size of hole required.

A carriage for rock-drills is described by C. F. J. Galloway.†

W. R. Hulbert ‡ describes the methods of hand-drilling with the Jackson hand-power drill.

The relative merits of air and electric rock-drills are set forth by G. E. Palmer.§ He points out that for rock-cutting, the blow given by a pneumatic hammer-drill is far superior to that obtained in an electric drill by converting rotary into reciprocating motion. It is claimed for electric drills that they are easy to instal, less expensive in first cost, and show great economy of power. These claims are allowed to be true, but are more than offset by high cost of maintenance, by loss of time due to breakdowns, and by difficulty in successfully insulating the drill and protecting the delicate parts from jar. Figures given by the writer of actual work done on black diabase during fifty-three consecutive ten-hour shifts are as follows:—

	Air Drill.	Electric Drill.
Actual hours drilling . .	317	100
Actual feet drilled . .	1279	253
Average feet per hour . .	4	2·55
Times stopped for repairs	0	17

The electric drill used in this work was considered to be the best type on the market. The maker of the air drills is not given.

J. Kšanda ‖ gives an account of the results achieved with a Siemens and Halske electric rock-drill of the percussive type in driving an adit level at Breth.

Mine-Supports.—A. A. Steel ¶ describes an improved method of framing square sets, suggested by M. K. Orr, using on all the members nothing but square tenons and shoulders, so that each timber can be completely framed with only one setting of the simplest type of machine.

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* *Iron and Coal Trades Review*, vol. lxxiii. pp. 14–15.

† *Proceedings of the South Wales Institute of Engineers*, vol. xxiv. pp. 427–438, with plate.

‡ *Mining World*, vol. xxiii. pp. 664–665.

§ *Engineering and Mining Journal*, vol. lxxxii. p. 289.

‖ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 373–378, 391–395, and 402–405, with eleven illustrations in the text and one plate.

¶ *Mining and Scientific Press*, August 11, 1906.

W. K. Hatt [*] gives an account of experiments on the strength of treated timber made at the experimental plant for investigating methods of preserving timber at the St. Louis Exposition. As the results of 6272 tests, the following conclusions were reached: (1) A high degree of steaming is injurious to wood; (2) zinc chloride does not weaken wood under static loading, but may render it brittle under impact; (3) the presence of creosote will not of itself weaken wood, but it appears to retard seasoning. Numerous tables embodying the detailed results of the tests are given.

The final stages in the work of piercing the Simplon Tunnel are described and illustrated.[†] The methods employed in excavating a distance of about 42 yards through soft decomposed clay slate are described. This operation was one of great difficulty and danger, owing to the treacherous nature of the material and the enormous earth pressures. The special methods of timbering and the iron and masonry supports are described.

Methods of Working.—W. H. Storms [‡] describes the application of the caving system at the Pewabic mine, Michigan.

S. R. Elliott [§] describes a method of mining soft ore without timbering.

W. R. Crane [||] gives details of cost of work at some of the Lake Superior mines.

Carl Wetzel [¶] makes some useful suggestions regarding the support of the hanging wall at working ends.

Dangers due to the rock pressure observed at the Przibram mines are discussed by H. Stefan,[**] who deals generally with this question.

Haulage in Iron Ore Mines.—W. R. Crane [††] describes the improvements in haulage recently introduced in the iron ore mines of the Birmingham district, Alabama.

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[*] *United States Department of Agriculture*, Circular 39, 1906.

[†] *Engineer*, vol. c. pp. 564–566, with fifteen illustrations.

[‡] *Mining and Scientific Press*, July 14, 1906.

[§] *Ibid.*, June 9, 1906.

[||] *Engineering and Mining Journal*, vol. lxxxii. pp. 645–647.

[¶] *Der Erz-bergbau*, 1906, pp. 651–653.

[**] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 253–257, with four illustrations.

[††] *Mining and Scientific Press*, August 25, 1906.

S. Schauberger * discusses the working results obtained in practice with mine locomotives of the benzene and compressed air types. Of these he describes several.

Winding.—Illustrated descriptions are given † of three types of winding engines recently built by Fullerton, Hodgart & Barclay, Limited, of Paisley. The first engine is designed for use on the Rand, and can hoist a load of 14,000 lbs. 1800 feet per minute. The drum is 11 feet in diameter and 3 feet wide, turned with a spiral groove for a 1¼-inch rope, one groove being cast in the steel cheek, in order to secure proper lead. In the second case, a load of 6000 lbs. can be lifted from a depth of 2300 feet at a rate of 1500 feet per minute. The third engine possesses coned wheels from 10 feet to 6 feet 2 inches taper, the width being 5 feet 1½ inches. All three engines illustrate many interesting points in recent practice.

S. A. Worcester ‡ shows types of self-tipping ore skips.

E. F. Roth § describes the application of telephone systems to mines, and the precautions to be observed in overcoming the difficulties presented by dampness, vibration, and inaccessibility.

Wire Rope Cappings.—A discussion || took place at a meeting of the Manchester Geological and Mining Society on May 9, respecting the relative advantages and disadvantages of various forms of wire rope cappings. J. Gerrard pointed out that in the ordinary forms in which the wires are turned back upon themselves, such cappings nearly always failed in actual use. F. L. Ward described a method of socketing the end of the rope by running in white metal to form a cone. The results not being perfectly satisfactory, magnolia metal was substituted in combination with pure tin, and the results of tests proved that this form of capping was highly efficient in practice.

E. King ¶ describes the construction of the Kilindo wire ropes and the method of attaching these ropes to colliery cages.

Mine Drainage.—A description of the methods adopted in the unwatering of the old Forest of Dean iron ore mine, Orange County,

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* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 157-162, with six illustrations.

† *Engineering*, vol. lxxxi. pp. 820–821.

‡ *Engineering and Mining Journal*, vol. lxxxii. pp. 387–388.

§ *Ibid.*, vol. lxxxi. p. 1002.

|| *Transactions of the Institution of Mining Engineers*, vol. xxix. pp. 625–635.

¶ *Ibid.*, vol. xxxi. pp. 150–154.

New York, has appeared.* The mine has been acquired by the Hudson Iron Company, and operations were commenced in October 1905. The old plant had to be dismantled, and two 72-inch Pelton wheels have been installed. The Cornish pump formerly used has been put in order again, and as it has a capacity of 175,000 gallons per twenty-four hours, it will suffice to keep the mine free from water after the unwatering has been completed.

G. Steuer † describes the present condition of pumping in ore mines.

R. J. Durley ‡ discusses the design and efficiency of high-lift turbine pumps. He considers that they have been shown in practice to give good results, particularly when directly connected to steam-turbines.

M. Ziegler § and J. Diviš describe the Sulzer high-pressure centrifugal pump. This is a paper that was read at the Liége Congress.

The Columbus impeller pump is described by E. K. Hood.|| It is simple in principle and construction, takes up very little room, and is convenient for mine work.

A. M. Patterson, junior,¶ describes the methods of mine pumping by compressed air.

The electric pumping plant at the Consett Ironworks is described.** The total capacity of the pumps installed is 8,600,000 gallons per twenty-four hours.

Lighting Iron Ore Mines.—W. Serlo †† describes the adoption of acetylene lighting in the Lorraine iron mines. At the present time 6000 iron miners in Lorraine, or more than half those employed underground, are using acetylene lamps.

Mine Surveying.—A. L. de Leeuw ‡‡ shows how surveying work of sufficient accuracy for many purposes may be done without instruments.

An account of the measurement of base lines with steel tapes has been published.§§ The base line measurements carried out in the Simplon Tunnel with "invar" wires by the Federal Geodetic Com-

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* *Iron Age*, vol. lxxvii. pp. 1972–1975.

† *Der Erz-bergbau*, 1906, pp. 480–483.

‡ *Engineering Magazine*, vol. xxxi. pp. 503–525.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp 185–187, 204–205.

|| *Iron Age*, vol. lxxvii. p. 1756.

¶ *Mining World*, vol. xxiv. p. 776.

** *Engineer*, vol. ci. pp. 32–33.

†† *Glückauf*, vol. xlii. pp. 513–523.

‡‡ *Machinery*, vol. xii. pp. 565–566.

§§ *Engineer*, vol. ci. p. 211.

mission are described by M. Gensbaur.* C. E. Guillaume † gives details of the rapid measurement of base lines. G. Szentistvanyi ‡ publishes a mathematical monograph on triangulation.

S. J. Pollitzer § discusses the conclusions of D. D. Scott respecting mine-surveying instruments. A quick survey of a vertical shaft is described by W. E. Downs.‖ L. Gluck ¶ discusses the graphic solution of mining problems.

E. Dolezal ** describes the mine-levelling instrument devised by O. Cséti. He also refers to modifications introduced by himself.†† E. M. Douglas ‡‡ gives the results of experience with the prism level on the United States Geological Survey.

A. Lakes §§ discusses the use of freehand sketching in preparing a topographical map.

History of Mining.—R. Cagnet ‖‖ presented to the Académie des Inscriptions a translation of a mining law found recorded in a Portuguese metal mine. The inscription is on a bronze slab, and dates from the reign of the Emperor Hadrian. A full translation is given.

Iron Ore Transport.—John Ernest Harrison ¶¶ describes the methods of unloading, storing, and shipping iron ore from the Alquife mines in the South of Spain. On arrival of the ore at Port Almeria, it is unloaded by hand and stored in heaps, from which it is filled into small baskets which are conveyed in mule waggons to the vessel, and thence carried by manual labour to the hold. By these means 1000 tons of ore can be dealt with in ten hours by employing 350 men. To minimise handling and the consequent breakage, a loading stage or pier, consisting of a steel superstructure resting upon foundation-columns of steel and concrete, has been constructed in deep water, capable of storing about 10,000 tons of ore at such an elevation that it could be discharged by gravitation into the holds of vessels lying alongside. The author describes the method of construction of the pier, and the approach line from the railway terminus. The first steamer was loaded from this pier on June 12, 1904, since when the pier has continued to serve its purpose successfully. Indeed vessels have been loaded with 8000 tons of ore in ten hours, and it is anticipated that with practice even better results will be attained.

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* *Zeitschrift des Oesterreichischen Ingenieur- und Architekten-Vereines*, vol. lviii. p. 376.

† *Nature*, vol. lxxiv. p. 281.

‡ *Banyaszati es Kohaszati Lapok*, vol. xxxix. pp. 593–632.

§ *Transactions of the Institution of Mining Engineers*, vol. xxix. pp. 551–555.

‖ *Mining and Scientific Press*, August 25, 1906.

¶ *Mining World*, vol. xxiv. pp. 31–32.

** *Zeitschrift des Oesterreichischen Ingenieur- und Architekten-Vereines*, vol. lviii. p. 235.

†† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 199–204, 214–218, 225–230, 243–245, 257–260, 276–279, and 283–286, with fifteen illustrations.

‡‡ *Engineering News*, vol. lv. pp. 536–537.

§§ *Mines and Minerals*, vol. xxvi. pp. 460–461.

‖‖ *Echo des Mines*, vol. xxxiii. pp. 1001–1002.

¶¶ *Minutes of Proceedings of the Institution of Civil Engineers*, vol. clxiii. pp. 300–308.

E. Siermann [*] describes recent improvements in methods of transporting raw materials.

M. Buhle [†] deals in considerable detail with the methods of storing and conveying the raw materials needed at works, and with questions connected with the subject. He gives details of the handling of material of lump, granular, or pulverulent character, and questions of cost are also dealt with. Continuous and other conveyors are described with various subdivisions, and storage appliances are similarly passed in review.

Recent improvements in American transporting appliances are described and illustrated by G. von Hanffstengel.[‡]

E. Winkelmann [§] describes various improvements in wire rope conveying appliances devised by J. Eibensteiner.

J. Douglas [||] discusses the relation of railway transport to mining and metallurgy in the United States, with special reference to the transport of iron ore from the chief sources of supply to the chief centres of the metallurgical industries.

H. Herner [¶] describes and illustrates the ore steamer *Narvik*, built for the iron ore trade between Narvik and Rotterdam.

P. Berkenkamp [**] observes that the industrial region of Rhenish-Westphalia stretches as a narrow district from the Rhine to the

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[*] *Chemische Zeitschrift*, vol. v. pp. 298–299.

[†] *Stahl und Eisen*, vol. xxvi. pp. 641–654, 714–722, 789–795, and 854–861, with fifty-six illustrations.

[‡] *Zeitschrift des Vereines deutscher Ingenieure*, vol. l. pp. 1345–1352, 1408–1414.

[§] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 166–167, 245–247, 288–289, 300–301, and 309–312, with twenty-seven illustrations.

[||] *School of Mines Quarterly*, vol. xxviii. pp. 1–19.

[¶] *Zeitschrift des Vereines deutscher Ingenieure*, vol. l. pp. 695–699.

[**] *Stahl und Eisen*, vol. xxvi. pp. 1033–1040, with one plate and five illustrations in the text.

Unna, bounded as to its sides by the rivers Lippe and Ruhr. These rivers were largely used for transport until the construction of the railways, but afterwards almost entirely ceased to be employed, as the transhipment of material from the small boats used on them to the larger ones of the Rhine proved excessively expensive. The canalisation and harbour arrangements subsequently introduced to overcome this difficulty are described, and the appliances used at the latter, as well as the arrangements generally, are dealt with and considered.

Details have appeared * of a scheme for the construction of a canal of a total length of about twenty-five miles, starting at Remich, on the Moselle, and terminating near Korn, in the neighbourhood of Rodange and Mont Saint Martin. By this means the Luxemburg centres of industry, including the works at Dudelingen and Differdingen, would be brought into relation with the Longwy basin of France, and it is thought that a large portion of the trade would then pass through France.

Handling Iron Ore.—D. A. Willey † describes the latest practices in the design and construction of ore-handling appliances on the great American lakes. The capacity of the appliances for loading may be gauged from the fact that at Duluth a fleet of fourteen vessels has been filled with 64,000 tons of ore in twenty-four hours, while the steamer *Wolvin* alone has taken 12,250 tons of ore on board in 1 hour 30 minutes, being at the dock only three hours altogether. The hoists, conveyors, and grabs employed are described and illustrated.

E. W. Pittman ‡ describes the construction, sizes, and types of ore bins.

III.—*MECHANICAL PREPARATION.*

Iron Ore Dressing.—Progress in ore dressing in 1905 is reviewed by R. H. Richards.§

G. G. Bring || gives the results of experiments on the action of jigging machines.

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* *Iron and Coal Trades Review*, vol. lxxiii. pp. 1171–1172.

† *Cassier's Magazine*, vol. xxx. pp. 195–211, with twelve illustrations.

‡ *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xxii. pp. 239–249.

§ *Mineral Industry*, New York, vol. xiv. pp. 604–639.

|| *Jernkontorets Annaler*, vol. lx. pp. 321–472.

J. H. Granbery[*] describes the means employed for separating the phosphoric apatite from the rich magnetite with which it is associated in the Old Bed mines at Mineville, New York. The material is crushed and separated by a Ball and Norton single drum separator.

Magnetic Separators.—J. F. Robertson[†] gives results of recent experiments in the concentration of the iron sands of the lower St. Lawrence. The difficulties to be overcome are the low percentage of iron owing to dilution with sand, the presence of an undue proportion of titanium and the fineness of the mineral. The last named can now be overcome by briquetting. An apparatus specially designed, and based on the principle of the Heberle drum separator, was used. The sand used in the experiments contained 57 per cent. of iron and 16·2 per cent. of titanic oxide. The strength of field of the magnets requires careful adjustment. A concentrate containing 70·46 per cent. of iron and 1·91 per cent. of titanic oxide was obtained, but an improvement in recovery could be obtained with higher amperage than was employed in the experiments. The capacity of the separator was about 100 pounds per hour.

H. Louis[‡] deals in detail with the dressing of iron ore, and gives illustrations of the Wenström, Gröndal, and Wetherill electro-magnetic separators, and the Blake-Morscher machine.

An illustrated description of the Dings magnetic separator is given.[§] The machine is of the low intensity induction type, the ore being presented to the magnets by means of an inclined shaking tray, supported on a heavy steel plate which acts as a magnetic armature to the pole pieces.

Recent progress in magnetic concentration is reviewed by L. Fabre.[||]

C. Bugge[¶] illustrates and describes the various types of magnetic concentrators.

The report of the Canadian Government Commission appointed to investigate the zinc resources of British Columbia[**] contains incidentally much information on magnetic separators collected by W. R. Ingalls.[**] The magnetic separators described are the Monarch,

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[*] *Engineering and Mining Journal*, vol. lxxxi. pp. 1082–1084.

[†] *Canadian Mining Review*, vol. xxvi. pp. 23–26.

[‡] *Journal of the Society of Chemical Industry*, vol. xxiv. pp. 1208–1212.

[§] *Engineering and Mining Journal*, vol. lxxxi. p. 749.

[||] *L'Electricien*, 1906, pp. 100–103, 121–124, with thirteen illustrations.

[¶] *Teknisk Ugeblad*, vol. liii. pp. 209, 217, 234.

[**] Ottawa, Canada, 1906, pp. 82–121.

Santter, Siemens and Halske, Heberle, Ferraris, Payne, Wenström, Buchanan, Mechernich, Siemens, Delvik-Gröndal, Conkling, Rowland, Wetherill, Cleveland-Knowles, Furney, Courtney and Knowles.

IV.—*METALLURGICAL PREPARATION.*

Roasting Iron Ores.—A furnace designed for roasting fine ore is described by A. Gradenwitz.* It is the invention of G. O. Petersson of Finland. The furnace is gas-fired, and the material to be roasted is fed at the top, either continuously or intermittently, and descends gradually to the bottom after a somewhat tortuous passage down the shaft. The inventor suggests the possibility of utilising iron ores containing titanium in this furnace, which can only deal with pulverised ores. With ores which contain much sulphur the roasting process may be repeated several times, the ore being washed between each operation.

Briquetting Iron Ores.—C. Bugge † describes the briquetting of pulverulent iron ores. The briquettes must withstand shock in transport. They must be able to resist the action of snow and rain, so that they can be stored in the open air. They must be porous, and consequently easily reducible. They must not be affected by steam at a temperature of 180° C. near the furnace top. Lastly, they must be coherent in the furnace until the reduction is nearly complete. The best results are obtained by briquetting without a binding material. The Gröndal process, which is successfully used at Bredsjö and Harrang, is best adapted for magnetite ores.

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* *Iron Trade Review*, July 19, 1906, pp. 17–19.

† *Teknisk Ugeblad*, vol. liii. p. 244.

REFRACTORY MATERIALS.

Fireclay.—G. Ristori * describes a bed of fireclay at Altopascio and Monte Carlo, province of Lucca, Italy.

H. Ries † describes the clays of Texas, giving an account of the geological occurrence of the deposits, and of the chemical and physical properties of the clays.

Manufacture of Fire-Brick.—A. F. Greaves-Walker, ‡ discussing fire-brick problems in metallurgy, states the points to be considered by the manufacturer of bricks for furnace linings are: the temperature attained, the chemical activity of the slags produced, the nature of the fuel used, and the abrasion in the furnace. By varying the proportions of plastic and non-plastic clay, the size of grain, the method of manufacture, and the temperature of burning, the manufacturer can easily control the physical properties of his product.

Graphite.—C. C. Schnatterbeck § describes the occurrence and uses of graphite.

The annual progress report of the Geological Survey of Western Australia for 1905 (Perth, 1906) shows that much interest has been taken locally in deposits of graphite, and those on the Donnelly River have been worked to a slight extent.

H. L. Barvir || discusses the origin of the graphite deposit at Schwarzbach in Southern Bohemia.

E. Donath ¶ deals with the method in use for the manufacture of graphite in the electrical furnace. The graphites are produced by heating suitable raw materials high enough and for a long time in

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* *Giornale di Geologia Pratica, Perugia*, vol. ii. pp. 43–49.

† *Bi-Monthly Bulletin of the American Institute of Mining Engineers*, 1906, pp. 767–805.

‡ *Iron Trade Review*, August 23, 1906, pp. 17–21.

§ *Mining World*, vol. xxiv. p. 580.

|| *Sitzungsberichte der kgl. böhm. Gesellschaft der Wiss., Mat. Nat. Kl.; Geologisches Centralblatt*, vol. viii. p. 331.

¶ *Stahl und Eisen*, vol. xxvi. pp. 1249–1255, with one illustration.

this type of furnace. Those made from anthracites vary considerably according to the type of anthracite used. Their densities vary between 2·20 and 2·25, and they burn in the air more readily than does Ceylon graphite. This appears to be due to reasons connected with their structure, for they resist even more than Ceylon graphite such an oxidising mixture as nitric acid and potassium chlorate. The purest graphite made is that obtained from petroleum coke. As marketed it contains less than 2 per cent. of ash, and is of very good quality. Other methods of producing graphite are also discussed.

Bauxite.—The use of bauxite as a refractory material is described by A. J. Aubrey.* Bauxite is found in North America in three districts—Arkansas, New Mexico, and in the Georgia-Alabama district. The percentage of water may vary, and a portion of the aluminium may be replaced by iron. Crude bauxite is freed from sand by washing and is then burnt. It is thereby considerably reduced in volume, and loses about 30 per cent. of its weight in water. Bauxite burnt and cleaned in this manner has the composition: water, 0·88 per cent.; silica, 6·40 per cent.; oxide of iron, 1·43 per cent.; alumina, 87·30 per cent.; titanic acid, 3·99 per cent. Burnt bauxite is mixed with refractory clay, lime or silicate of soda, and made into bricks. The bricks made up with lime harden after a short time, owing to the formation of silicate of calcium. For basic open-hearth steel furnaces only bauxite with a high percentage of alumina and a low percentage, maximum 12 per cent., of silica can be employed. At the Bethlehem Steelworks comparative tests with magnesite and bauxite bricks in the hottest part of the hearth have been made. The magnesite bricks began to soften after seven minutes, and the bauxite bricks only after fifteen minutes. The behaviour of both in contact with melted slag was determined. Magnesite was during the same time completely impregnated with slag, and with bauxite it only formed a thick covering. Bauxite with a low percentage of silica is a very refractory material, and is very suitable for lining rotary cement kilns and lead-refining furnaces.

Crucibles.—Fred Hood † points out that crucibles should be refractory, able to resist the chemical and mechanical influences of the melted metals, and capable of supporting sudden changes of temperature. The raw materials and the most usual additional substances employed in the manufacture of crucibles are dealt with, details being given of the manufacture of graphite and magnesia crucibles.

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* *Mineral Industry*, New York, vol. xiv. pp. 48–51.

† *Giesserei Zeitung*, 1906, p. 295.

The Refractory Nature of Furnace-linings.—The following average temperatures at which the cast metal arrives in the mould have been determined by W. Heym:[*] Aluminium, 690° C.; ordinary cast iron, 1000° C.; white cast iron, 1230° C.; grey cast iron, 1350° C.; steel, 1500° to 1600° C. The linings of the furnaces and of the moulds must be selected to withstand these temperatures respectively. A short report of the experiments of Boudouard are given, by which the melting point of pure silica was fixed at 1830° C. By mixing silica with 14·5 per cent. alumina the melting point descends from 1830° to 1690° C. A further addition of alumina allows the melting point to rise again, until with 37 per cent. silica and 63 per cent. alumina, 1890° C. is attained. With mixtures of silica and lime the melting temperature descends at first until the proportions 60 per cent. silica and 40 per cent. lime is reached, and from this point it begins to rise again. Mixtures of silica, alumina, and lime gave unfavourable results, because the melting temperature fell considerably.

Magnesite.—F. L. Hess[†] describes the working of magnesite deposits in California, giving particulars of their extent, character, development, and uses.

The present stage of development and the prospects of the magnesite mines of South Africa are described.[‡] They are situated between Kaapmuiden and Malelane, 87 miles from Delagoa Bay and 300 miles from Johannesburg. The magnesite occurs in nearly vertical beds associated with serpentine in schists, and is worked in open cuttings. The magnesite is of good quality, and the mines have opened out an industry that is likely to be of considerable future importance.

The opening up of important deposits of magnesite near Ochtina, Gömör County, Hungary, is recorded.[§]

Carborundum Bricks.—L. Bérda[‖] describes the various refractory materials shown at the Liége Exhibition, and devotes special attention to the exhibits of carborundum bricks shown by the Thonwerke Aktiengesellschaft, of Arloff. The carborundum employed is obtained by fusing sand and coke in the electric furnace. The carbide of silicon (carborundum) thus produced is infusible, and absolutely resistant to acids, while even at 1000° neither oxygen, chlorine, nor sulphuric acid exert any influence upon it. The only solvents are iron and steel, and molten carbonates of the alkalies. Carborundum linings are made by binding pulverulent carborundum by means of fireclay or sodium silicate. Such linings are exceedingly durable, and may be used to protect bricks used in furnaces, ladles, &c.

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[*] *Giesserei Zeitung*, vol. iii. p. 458.

[†] *Engineering Magazine*, vol. xxxi. pp. 691–704.

[‡] *Engineer*, vol. cii. p. 274.

[§] *Montan Zeitung*, vol. xiii. p. 270.

[‖] *Revue Universelle des Mines*, vol. xii. pp. 158–170.

FUEL.

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I.—*CALORIFIC VALUE.*

Calorimetry.—C. V. Boys[*] describes a new form of gas calorimeter, free from the disadvantages possessed by many of the previously invented instruments. It can be entirely taken to pieces and examined in a few minutes. A feature peculiar to this calorimeter is the absence of water-cooling from all but the lower end of the chimney. Being made of copper $\frac{1}{16}$ inch thick, with its base in contact with water, it is prevented from becoming hot enough to burn, while at the same time it is so hot that condensation does not occur on its inner surface, and the collection of condensed water is simplified.

W. Rosenhain[†] has devised a method for the calorimetric determination of the heat value of volatile liquids, such as petrol, which are being increasingly employed in explosion motors, and for other purposes in which an accurate determination of the heats of combustion is useful. The liquid to be investigated is absorbed by cellulose material of known calorific value, with which it is made into pellets. For heavy liquids accurate results can be obtained in this way, but for volatile liquids it is necessary to wrap the pellet in tinfoil to avoid evaporative losses. The calorific value of the tinfoil requires of course to be ascertained and deducted. The details of the method and the manner of calculating the results are described.

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[*] *Proceedings of the Royal Society*, vol. lxxvi., Series A, pp. 122–130.

[†] *Journal of the Society of Chemical Industry*, vol. xxv. pp. 239–241.

T. Gray * describes an improved form of the Thomson calorimeter. The chief differences in this instrument as compared with the older forms are (1) the replacement of the bulged-glass combustion chamber by a straight and somewhat wider glass tube; (2) the substitution of thin perforated brass discs for the original wire-gauze baffles; and (3) the provision of electrical devices for igniting the coal.

J. W. Bain † and J. W. Batten describe a recording calorimeter for gases, and discuss the relation of flame temperature to calorific power.

W. M. Wallace ‡ has designed an alcohol calorimeter for coal-testing on the Carpenter principle. The irregular expansion of the water in the latter is remedied in the present instrument by the use of alcohol, while, as a smaller amount of coal only requires to be used, the duration of the test is sensibly reduced.

The use of platinum thermometers in the calorimetric work of the Reichsanstalt is described by W. Jaeger § and H. von Steinwehr. The methods and the calculations involved are fully explained.

E. J. Constam || and R. Rougeot find as the result of exhaustive experiments that the Parr calorimeter has a constant error, and advise care in working with this apparatus.

Pyrometry.—A. Lampen ¶ describes an electrical resistance furnace for the measurement of high temperatures with the optical pyrometer.

W. H. Bristol ** describes a low resistance thermo-electric pyrometer for ranges of temperature not exceeding 2000° F. The elements employed are alloys of tungsten, steel, nickel, iron, and copper, and a number of small improvements have been effected in the general design and construction of the instrument, which can be made self-recording.

Pillier †† describes a number of thermo-electric pyrometers, which can be given into the hands of workmen.

A description has appeared ‡‡ of a new automatic recorder for high temperatures. It is designed by Baird and Tatlock, and consists of a

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* *Journal of the Society of Chemical Industry*, vol. xxv. pp. 409–411.

† *Ibid.*, pp. 505–507.

‡ *Engineering*, vol. lxxxi. pp. 527–528.

§ *Zeitschrift für Instrumentenkunde*, vol. xxvi. p. 237.

|| *Zeitschrift für angewandte Chemie*, vol. xix. pp. 1796–1806.

¶ *Journal of the American Chemical Society*, vol. xxviii. pp. 846–853.

** *Iron Age*, vol. lxxvii. pp. 1610–1612.

†† *Bulletin de la Société Internationale des Electriciens*, 1906, pp. 183–194.

‡‡ *Iron and Coal Trades Review*, vol. lxxiii. p. 1258.

D'Arsonval galvanometer, the suspended coil of which carries a metal pointer which is free to move over two metallic pieces insulated from one another. One of the pieces is connected to one terminal of an electromagnet, and the other to one terminal of a similar electromagnet. The opposite terminals of each of the electromagnets are connected to one and the same pole of a local battery. The other pole of the battery is connected with a movable metal arm, which by means of clockwork descends periodically on to the movable pointer already described, and clutches it between the arm and (1) either of the two metallic pieces, or (2) the insulation, according to the position of the pointer. When at work the record is almost entirely visible, and the instrument can be used at any distance from the source of heat.

Fuel Value of Coal.—The heating power of various coals is shown in graphic form by G. Baum.*

E. Graefe† investigates the influence of oxygen containing hydrogen on the determination of the calorific value. In oxygen prepared by electrolysis, almost always, varying amounts of hydrogen, which may equal as much as 4 volumes per cent., are to be found. In calorimetric tests this hydrogen burns partly, and the results obtained are too high. The author has discovered that only so much hydrogen burns as is present in that quantity of oxygen which is consumed in the combustion of the substance to be tested. For this reason the error, about 180 calories for each percentage of hydrogen, remains constant for variable quantities of matter, and the consumption of oxygen being approximately proportional to the heating value, the error for different fuels is approximately an equal percentage. It is necessary to determine the percentage of hydrogen in the oxygen in order to correct all results obtained.

H. S. Knowlton ‡ deals with the importance of constantly checking industrial operations involving the use of fuel by coal tests, and the advantage of buying coal on the results of such tests rather than on the strength of chemical analyses. The best form of test is the practical application of the coal under examination in the boiler-room, but careful sampling of large lots may also lead to economy.

The combustion of coal is discussed by R. S. Moss.§

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* *Glückauf*, vol. xlii. pp. 1001–1014.

† *Journal für Gasbeleuchtung und Wasserversorgung*, August 4, 1906.

‡ *Cassier's Magazine*, vol. xxix. pp. 289–292.

§ *Mining World*, vol. xxiv. pp. 552–553.

II.—*COAL.*

Origin of Coal.—L. Lemière* continues his investigations on the chemistry and stratigraphy of fossil fuels, and deals with the mechanism of the deposition of coal in seams, and the part played by salt-water in the sedimentary stratigraphy of the beds as they now occur. He deals with the mathematical aspects of stratification, the angle of repose, and the levigation of particles, and employs his deductions to support his previously elaborated theory of the bacterial origin of coal. He concludes his investigations on the formation, the comparative chemistry, and stratigraphy of fossil fuels, and summarises a number of theories which have been put forward to account for the origin of coal. He concludes that bacterial action supplies the most satisfactory explanation of the formation of coal from vegetable remains that has yet been advanced.

J. Ford † discusses the origin of coal, and theorises as to the formation and occurrence of coalfields. He contends that the coal-seams now found were once vast swampy peat-bogs or masses of vegetation forming in immense areas of standing water, accumulating for long periods of time and in favourable climatic conditions, after which the land gently subsided, and the accumulated vegetation became covered over with a layer of mud, or sand brought down by rivers from more elevated places, or an encroachment of the sea; and then as time passed on, either from the large amount of sediment brought down, or from the gradual uprising of the land, this new surface would again be exposed to the favouring conditions of light and heat, and other harvests of vegetation would grow and accumulate, and they also in turn would become covered over in a similar manner. This phenomenon would occur again and again, and as a matter of fact is still taking place, and thus numbers of coal-seams have been formed and brought within man's reach.

Some palæontological observations on the mode of formation of the Belgian coal deposits are published by A. Renier.‡

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* *Bulletin de la Société de l'Industrie Minérale*, vol. iv. pp. 1249–2383; vol. v. pp. 273–349.

† Paper read before the National Association of Colliery Managers, June 30, 1906; *Iron and Coal Trades Review*, vol. lxxiii. pp. 116–117.

‡ *Annales de la Société Géologique de Belgique*, vol. xxxii. pp. 261–314.

The formation of coal is discussed by M. R. Campbell,* by R. Hodurck † and U. Söhle, and by W. N. Page.‡

W. Baldwin § describes the occurrence of Prestwichia anthrax and Belinurus lunatus from Sparth Bottoms, Rochdale.

P. Frazer ‖ defends the system of classification of coals proposed by him some years ago, from the criticisms of M. R. Campbell.¶

J. C. Gwillim ** discusses current theories as to the genesis of coal, and the conditions under which coal-bearing strata have been built up. He gives tables showing the composition of Canadian coals, which reveal the gradual transition from a watery lignite to a graphitic anthracite. The conditions which accompany the occurrence of the semi-bituminous and semi-anthracitic coals of Western Canada seem to show that they are the result of alteration chiefly by pressure.

Coal in England.—J. Dickinson †† describes the geology of the Lancashire coalfield. The field is semi-circular, with unconformable New Red Sandstone and Permian at the chord under which it dips. It is dislocated by large faults, attended by dips and changes of strata. The largest fault has corresponding strata 1000 yards higher at one side than at the other, although the surface of the ground is levelled off to the same altitude on both sides. Vast areas of the best coal-seams at moderate depths have been worked, and places for new winnings within the area of the coalfield proper are few and difficult to find.

A short description has appeared ‡‡ of the new sinking at the Brodsworth Colliery in the Barnsley seam. The coal is believed to occur at a depth of 658 yards below the surface, but as a fault is suspected to exist in the vicinity of Adwick-le-Street, the ultimate depth will probably be greater. Plant will be installed to deal with an output of 5000 tons per working day. About 120 sinkers will be employed continually on three shafts, and the sinking operations are expected to occupy fully two years.

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* *Economic Geology; Colliery Guardian*, vol. xcii. pp. 601–602; *Science and Art of Mining*, vol. xvii. p. 157.

† *Braunkohle*, vol. iv. pp. 173, 189.

‡ *Mining World*, vol. xxv. p. 158.

§ *Transactions of the Institution of Mining Engineers*, vol. xxix. pp. 621–625.

‖ *Bi-Monthly Bulletin of the American Institute of Mining Engineers*, 1906, pp. 239–246.

¶ *Ibid.*, 1905, pp. 443–484; *Journal of the Iron and Steel Institute*, 1906, No. I. p. 327.

** *Journal of the Canadian Mining Institute*, vol. viii. pp. 235–240.

†† *Transactions of the Institution of Mining Engineers*, vol. xxx. pp. 357–368.

‡‡ *Engineer*, vol. ci. p. 357.

Coal in Scotland.—E. B. Bailey[*] and D. Tait describe the occurrence of true coal measures at Port Seton, East Lothian.

Coal in Hungary.—J. Andreics[†] and A. Blascheck describe at considerable length the Zsyltal collieries of the Salgó-Tarjan Colliery Company. The coal mined has a calorific power which varies between 5408 and 6960 calories, according to the various seams. An analysis of the coal shows:—

Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.
68·89	4·97	13·09	1·06	5·73

together with 2·08 per cent. of combustible sulphur, and 4·18 of hygroscopic moisture. Resembling in appearance a bituminous coal, it is nevertheless a brown-coal. It is partly mined open-cast. The output in 1905 was 813,992 metric tons. The methods of mining adopted are described and illustrated. The workpeople employed number 4724.

Coal in Belgium.—W. O'Connor[‡] sketches the relation of the Carboniferous rocks of Belgium to the overlying Cretaceous and Tertiary beds. The most recent facts regarding the extension of the Westphalian coalfield are recorded.

O. Ledouble[§] gives an exhaustive description of the mine map of the Liége coalfield.

Coal in France.—The results of the search for coal in French Lorraine are recorded by C. Cavallier.[||]

F. Laur[¶] describes the search for coal in the Lorraine district, and the geology of the field.

The Lorraine coalfield is described by J. Bergeron.[**]

Coal in Germany.—B. Schulz-Briesen[††] gives a detailed description of the geology of the western extension of the Saarbrücken coal measures into German Lorraine and France.

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[*] *Transactions of the Edinburgh Geological Society; Colliery Guardian*, vol. xci. pp. 781–782.

[†] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 461–467, 475–481, 494–498, 508–511, 520–523, 531–535, with two plates and other illustrations in the text.

[‡] *Proceedings of the South Wales Institute of Engineers*, vol. xxiv. pp. 457–506.

[§] *Annales des Mines de Belgique*, vol. xi. pp. 3–55.

[||] *Bulletin de la Société Belge de Géologie*, vol. xix. pp. 483–497.

[¶] *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1906, pp. 264–292.

[**] *Ibid.*, pp. 302–307.

[††] *Glückauf*, vol. xlii. pp. 737–742.

P. Geisenheimer [*] gives a geological description of the coal measures of Upper Silesia and Moravia.

F. Heinicke [†] describes the Upper Miocene brown-coal deposits at Sorau in the province of Brandenburg, and at Hausdorf in Silesia.

H. Meyer [‡] gives a geological description of the coal measures between Dortmund and Camen. The paper is illustrated by three coloured maps.

H. Mentzel [§] discusses the movements to which the Gelsenkirchen anticline has been subjected.

Coal in Russia.—S. Konkiewicz [||] and W. Baumann describe the occurrence of coal in the Dombrowo basin, Poland, and estimate that there are 824 million tons still unworked.

A. M. Ossendowsky [¶] describes the coals of the far-eastern portion of Russia. The coals of the Ussuri District vary in age from the more recent Tertiary to Palæozoic. The more recent coals are the most important commercially. In the Pervaja Retschka district, in the neighbourhood of Vladivostok, is a brown-coal containing in the dried state—

Carbon.	Hydrogen.	Oxygen + Nitrogen.
61·92	5·24	19·68

In its ordinary condition it yields 40·91 per cent. of volatile constituents, contains 6·25 per cent. of moisture and 12·34 per cent. of ash, with 0·51 to 0·85 per cent. of sulphur. Another coal of deep black colour from the Swjato-Makarjevsky district yields—

Moisture.	Ash.	Volatile Constituents.	Ash-free Coke.
1·02	26·22	14·98	57·78

Other examples showed up to 63·27 per cent. of ash-free coke. This last deposit is about fourteen miles from Vladivostok. Coal from the Podgorodnensky pits on the Ussuri Railway yields about—

Moisture.	Ash.	Volatile Constituents.	Ash-free Coke.
0·50	12–14	14·5 – 16·1	69·6 – 72·1

and gives, as shown by calorimetric tests, from 7010 to 7185 calories.

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[*] *Zeitschrift des Oberschlesischen Berg- und Hüttenm. Vereins*, vol. xlv. pp. 293–310.

[†] *Braunkohle*, 1906, pp. 113–116, 145–151, 225–228.

[‡] *Glückauf*, vol. xlii. pp. 1169–1186.

[§] *Ibid.*, pp. 693–702.

[||] *Rigasche Industrie-Zeitung*, vol. xxxii. p. 31; *Chemiker Zeitung, Repertorium*, vol. xxx. p. 127.

[¶] *Gorny Journal*, vol. lxxxi. Nos. 7 and 8; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 325–329, 339–343.

A series of brown-coals, of which assay results are given, show from 24·2 to 31·8 per cent. of volatile constituents, and 49·2 to 56·2 per cent. of ash-free coke. Assay results of other types of coal are added. Some of the coals contain up to 84 per cent. of ash-free coke, and are of anthracitic character.

Seams of brown-coal occur in the Bight of Retschnoj, the coal yielding 41 to 71 per cent. of volatile constituents. Analytical results are given for a number of these. Some other kinds of coal are also met with here.

Numerous deposits of coal are known on the island of Sakhalin. Samples taken from various places, of which the author gives assays and analyses, show from 24·81 to 73·78 per cent. of ash-free coke.

A number of analyses are given from Manchuria, the samples being mostly brown-coal. Graphite has been found in several places, the names of which the author gives. The samples analysed contained from 94 to 99 per cent. of carbon.

Coal in India.—W. R. Dunstan* gives a supplementary report on the composition and quality of a series of Indian coals. Determinations of the proportion of moisture and of phosphorus contained in the coals have been made, and the results of the work are given in a series of tables.

C. M. P. Wright† describes the Dandli coalfield in the Jammu State. The country is mountainous, rising at Ranjoti Station to 6250 feet. The coalfield is an extension of that at Jammu. The coal occurs in the limestone formation as two seams, with irregular strings of an inch or two in thickness. Outcrops are numerous, and when not obscured by debris are seen to be continuous. The coal is neither of good quality nor of any considerable thickness; and, bearing in mind the absence of local demand and the distance of the field from the railway, does not appear to offer any inducement to exploitation.

T. D. LaTouche‡ and R. R. Simpson report on the Lashio coalfield in the Northern Shan States. The coal-field lies in the upper part of the valley of the Nam-yan, which drains the greater portion of the Northern Shan States, and its average height above sea-level is about 2000 feet. The low hills of the valley are mostly composed of sandy clays and soft sandstones, a few bands impregnated with oxides of iron, and the coal being the only outcrops of anything like solid rocks in the whole field. The beds are extremely pervious to water, and since the coal-seams lie below the level of permanent saturation, there would be great difficulty in keeping the mines open. Seams aggregating 33 feet 3 inches are found in the bed of the Nam-yan, half a mile west of the village of Hsunkwe, and other seams are encountered at localities not far distant. There is little variation in the quality of the coal found. It is a brown-black lignite with a high percentage of moisture, a semi-conchoidal fracture, and a specific gravity of 1·53. It burns poorly in the open, with a dull flame and sulphurous odour, and it weathers badly on exposure to air.

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* *Records of the Geological Survey of India*, vol. xxxiii. pp. 241–253.

† *Ibid.*, vol. xxxiv. pp. 37–39.

‡ *Ibid.*, vol. xxxiii. pp. 117–124.

The Namma, Man-se-le, and Man-Sang coalfields in the Shan States are described by R. R. Simpson.* The first-named is about 15 miles long and 3½ miles wide. Some of the coal is hard and bright, but the bulk of it appears to be of inferior quality. An outcrop, varying in thickness from 7 to 17 feet, has been proved for 2400 feet. The only seams of economic importance are the thick seam east of Namma and the Mong-Ting seam. The estimated quantity of coal available is about 500,000 tons. Native labour being inefficient, it would be necessary to import Chinese labourers to make the mining of coal a commercial success. The Man-Sang coal is also a lignite, generally speaking of inferior quality. The Man-se-le coalfield calls for no particular mention, and has but few features of interest.

Coal in British North Borneo.—According to the report of W. G. Darby,† the coal measures near Tawao, British North Borneo, are being opened up, and shipments on a small scale are taking place. It is intended to store coal in bulk at Sandakan, and it is expected that this will prove an attraction and convenience to shipping.

Coal in Canada.—The summary report ‡ of the Geological Survey of Canada for 1904 indicates considerable activity in all quarters of the Dominion. A striking illustration of the usefulness of the survey lies in the discovery of a coal-seam 10 feet thick in a bore-hole 2340 feet deep in Cumberland, Nova Scotia. This bore-hole was sunk through a thick cover of unproductive rocks at the suggestion of Hugh Fletcher, after he had worked out the structural geology of the district.

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* *Records of the Geological Survey of India*, vol. xxxiii. pp. 125–156.

† *Foreign Office, Annual Series*, No. 3715.

‡ *Sessional Paper*, No. 26, Ottawa, 1906.

The report contains much information regarding the occurrence of coal in the Dominion. R. G. McConnell states that lignite of good quality occurs throughout the Tertiary area extending along the foot of the St. Elias range. H. S. Poole describes the Nanaimo-Cornox coal-field, British Columbia. D. B. Dowling gives an account of the northern extension of the Elk River coal basin. D. D. Cairnes reports the occurrence of lignite of very good quality in the foot-hills of the Rocky Mountains south of the main line of the Canadian Pacific Railway.

The coal outcrops near the Telkwa River, British Columbia, are described.* Development is being carried out by the Cassiar Coal Company, and the coal, which is bituminous and of good quality, is believed to be present in considerable quantity. The geology of the district is described, and sketch plans of the various formations are given. Much of the country is covered with heavy vegetation, which renders exploration impossible.

C. M. Henretta † deals with the occurrence of coal at the Bankhead mines near Banff, in the Rocky Mountains. The measures are of Cretaceous age, and the coal appears in the lower seams to have been changed from a bituminous character to one more closely resembling anthracite. The top seams remain bituminous. The coal is of a soft, friable nature, and it has been found necessary to leave thick pillars. The No. 1 seam has a thickness of 9 feet, and the No. 2 seam is 8 feet thick, the coal being of better quality. It averages 8 per cent. of ash, burns with a blue flame, and being semi-anthracitic in character, is practically smokeless.

D. B. Dowling ‡ describes the stratigraphy of the Cascade coal basin in the Rocky Mountains. In the Cretaceous formations there are three horizons which are coal-bearing—the lower portion, or the Kootenay series, which comprises the Crow's Nest Pass coalfields; the middle portion, or Belly River series; and the lignite tertiary, which includes the Edmonton series in Northern Alberta. The Kootenay series is the most ancient and contains the best quality of coal. At Bankhead there are, too, very regular and little disturbed seams. The lower seams are semi-anthracitic.

Coal in Natal.—A description is given of the coal resources of Natal.§ The chief district is the neighbourhood of Elandslaagte, but a coalfield, having an area of 1350 square miles, occurs in the Klip River County. In Northern Zululand another field exists, estimated to have an area of 800 square miles, the coal from which is hard and resembles those of the North of England. Careful tests have been carried out by the Government, with satisfactory results.

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* *Iron and Coal Trades Review*, vol. lxxiii. pp. 8–9.

† *Journal of the Canadian Mining Institute*, vol. viii. pp. 215–220.

‡ *Ibid.*, pp. 221–243.

§ *Engineering*, vol. lxxxi. pp. 23–24

Coal in the Transvaal.—H. Kynaston * gives a detailed account, with two geological maps and six sections of shafts and bore-holes and seven views, of the character, behaviour, and distribution of the coal-bearing strata of the Komati Poort district. Coal from a bore-hole near Furley's Drift contained 62·10 to 77·70 per cent. of fixed carbon and 20·70 to 36·0 per cent. of ash.

Coal in Victoria.—E. J. Dunn † states that at Korumburra there are immense deposits of shale in the Jurassic beds, and the coal is generally associated with shales. In the Bass Valley, in the vicinity of Woolamai, a good seam, probably identical with the Great Victorian seam, was traced in 1905 by bores for some distance. Other seams of more or less importance are known to exist in different parts of the district. The coal is of excellent quality.

Coal in Colorado.—R. M. Hosea ‡ describes the Floresta anthracite mine, Colorado.

Coal in Dakota.—Some important deposits of lignite in North Dakota are described by F. A. Wilder.§ In one case there is a 40-foot bed made up of a good quality of lignite.

Coal in Illinois.—R. S. Moss || describes the Carterville seam with special reference to the Peabody mines, Southern Illinois.

Coal in Maryland.—A report on the coals of Maryland has been published by W. B. Clark.¶

Coal in Missouri.—In a report on the geology of Moniteau County, F. B. Van Horn ** describes the coal deposits. The coal

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* *Transvaal Mines Department, Annual Report of the Geological Survey for* 1905, pp. 19–26.

† *Annual Report of the Geological Survey of Victoria*, 1905. Melbourne, 1906.

‡ *Engineering and Mining Journal*, vol. lxxxii. pp. 399–401.

§ *Economic Geology*, vol. i. pp. 674–681.

|| *Mining World*, vol. xxv. pp. 66–67.

¶ *Maryland Geological Survey*, vol. v. pp. 219–636.

** *Missouri Bureau of Geology and Mines*, vol. iii., 104 pages, with twenty-four illustrations and thirteen plates.

occurs in pockets, and not in the form of regular seams underlying any considerable portion of the area. It is mostly of the cannel variety, and is usually associated with a poor grade of bituminous coal.

Coal in New Mexico.—C. R. Keyes[*] gives particulars of the Carboniferous coal-measures recently discovered in New Mexico.

Coal in Ohio.—J. L. Pultz[†] describes the geology of the Pittsburg or No. 8 seam in Ohio.

Coal in Utah.—A. Lakes[‡] describes the geology of the lignite deposits bordering on the eastern slope of the Wasatch range, Utah.

Coal in West Virginia.—H. W. Althouse[§] describes the Pocohontas coals of the Pottsville series in Raleigh and Wyoming Counties, West Virginia. The area under review can be divided into three distinct parts, the geology of each of which is described. The Pocohontas coal-beds are in the middle division, in the lower portion of which the celebrated No. 3 coal occurs. This seam varies in thickness from 5 to 10 feet.

Coal in the Rocky Mountains.—E. A. Ritter[||] deals with the deposits of lignite and coal in the Rocky Mountains. These deposits can be grouped into two classes—those of Carboniferous age, and those of more recent formation, such as the Cretaceous or the Tertiary. The lignite deposits are of much later date, and are found at much smaller depths than those of France or Belgium. In the area of the eruptive rocks a semi-lignite is found, which ranges in quality from bituminous coal to anthracite, and, in extreme cases, to natural coke. Numerous analyses of coal found in the Rocky Mountains are given, ranged under the various States in which they occur, namely Montana, Utah, Wyoming, Colorado, and New Mexico. Tables affording means of comparison are also given relating to the coals of Washington, Oregon, British Columbia, and Alaska. The analyses given show that the coal ranges in quality from lignite containing a large proportion of combined water, up to pure anthracite. The coalfields dealt with may be roughly subdivided into four great centres: (1) The fields of Mexico in the South; (2) the central area, including the coalfields of Colorado, New Mexico, Utah, and Wyoming; (3) the coalfields of Montana and of Central British Columbia; (4) those of the Pacific Coast. The coal deposits form two long zones running north and south on both flanks of the Rockies, broken in the States of Idaho, Nevada, and Arizona. The most important fields in British Columbia are in the vicinity of the Canadian Pacific Railway, and are, respectively, the Cascade and the Crows' Nest Pass Fields. In Montana the chief fields are Bull Mountain, where horizontal seams of lignite occur over an area of many miles extent. The thickest seams vary in width from 10 feet at the eastern extremity to 16½ feet on the western edge. The most important workings are at Sandcoulée. The occurrence of coal in Laramie, where a number of valuable seams occur, is also recorded. The quality of the coal resembles that found at Cinnabar and in the Yellowstone. The author deals at some length with the lignites of Wyoming, and describes the geology of the State, as well as that of Colorado, in which both lignite and ordinary bituminous coals are found. The deposits in Trinidad-Raton furnish excellent coke. The deposits in Utah are of the same geological age as those of Wyoming and Colorado. Only those furnishing the best quality of coal are worked at present, as the supply of fuel in this district is considerably greater than the demand. After describing the remaining fields and the first three groups, he gives details as to the occurrence of coal and lignite in the State of Washington, after which he describes the variations in practice which occur in working in different localities. Statistical returns of the production of coal from the year 1860 to 1905 are given, with a series of tables showing the annual production per workman employed, and particulars as to the employment of mechanical coal-cutters. He believes that the resources of the Rocky Mountain coalfields are destined to be greatly developed in the near future, and that for many years to come they will supply large quantities of coal.

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[*] *Engineering and Mining Journal*, vol. lxxxi. p. 1129.

[†] *Ibid.*, vol. lxxxii. pp. 350–353.

[‡] *Mines and Minerals*, vol. xxvii. pp. 61–62.

[§] *Mining Magazine*, vol. xiii. pp. 200–212.

[||] *Annales des Mines*, vol. x. pp. 1–84.

Coal in the Philippines.—H. L. Wigmore * records the results of diamond drilling in the Philippines, and traces the development of the coal deposits of Batan island.

Coal in Asia Minor.—The various occurrences of coal and of lignite in Asia Minor are enumerated by C. Schmeisser.†

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* *Mines and Minerals*, vol. xxvi. pp. 529–536.

† *Zeitschrift für praktische Geologie*, vol. xiv. p. 193.

Coal in China.—The Hsüan Hua coalfields, China, are described by N. F. Drake.*

The Shantung Mining Company's resources are described.† The company has continued the development of the Fang-tse mine, and has sunk the main shaft to a depth of 826 feet in order to reach the lower deposit. The upper stratum, which has hitherto been worked, is at a depth of 574 feet. The output of the mine has reached 430 tons per diem. The sinking of a second shaft in the Wei-hsien coalfield, in the neighbourhood of the Chang-lo-yuen Railway Station, was commenced on June 6, 1904, and by the end of the year had reached a depth of 321 feet. It is hoped that this shaft will strike the upper coal deposit of the Fang-tse mine at a depth of about 1100 feet. Experimental borings had shown the presence of seams of good steam coal, 6 and 4 feet thick, at depths of 197 and 575 feet respectively. If the new shaft realises these expectations the mine will be an important one.

Coal in Manchuria.—H. Hiraoka ‡ deals with the coal resources of Manchuria, with special reference to the deposits at Fushan, where 1200 millions of tons of coal are in sight, the beds being 50 feet thick and 37 miles long.

Coal in Japan.—E. Lozé § discusses the coal resources of Japan. The deposits belong to secondary or mesozoic formations, and, with the exception of the island of Sikoku, in which they appear to be absent, are found in abundance in the three large islands of Jesso, Honshiu, and Kiu-Siu, and in the smaller islands to the north-west. Japanese coal is, as a rule, bituminous, although deposits of anthracite and of natural coke also exist. The proximity of the deposits to the sea-coast, combined with the costliness of the transport of fuel to the East from European ports, have permitted Japan to become mistress of the coal trade of the Far East.

Coal in Siam.—W. A. R. Wood || reports that he has been shown several pieces of coal and also a hard substance, apparently lignite, which has been picked up in the sands of the Chiengrai River, Siam.

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* *Mining Magazine*, vol. xiii. pp. 295–302.

† *Iron and Coal Trades Review*, vol. lxxi. p. 2129.

‡ *Engineering*, vol. lxxxi. pp. 21–22.

§ *L'Economiste français*, February 10, 1906; *Génie Civil*, vol. xlviii. p. 390.

|| *Foreign Office, Annual Series*, No. 3695.

These have, it would seem, been washed down by one of the smaller streams flowing into the Melok, and it would appear from their jagged edges that they have not come very far. The presumption, therefore, is that coal exists not very far from Chiengrai. On the advent of the railway this discovery is likely to prove of importance.

Coal in Portuguese South Africa.—R. C. F. Maugham [*] reports that extensive coal deposits have been found in the portion of the Zambesi Valley, and some activity in the Tetē region is not improbable at an early date.

Coal in Argentina.—A. C. Ross [†] has drawn up a report upon a coal deposit at Salagasta, near Mendoza, from which it appears that the coal is a large mass, the centre of which runs more or less north and south, some 5½ miles in length, and averages about half a mile wide. It is situated at Los Corrillos, some 7 miles distant from the Argentine Great Western Railway, between the stations Panqueau and Jocoli. The coal has not yet been put on the market except in small quantities for domestic use locally.

Coal in Peru.—A monograph on the mineral resources of the province of Cajamarca has been published by F. Malaga Santolalla. [‡] The work covers eighty-three pages, and is well illustrated and furnished with maps and sections. The coalfields of the province are of considerable importance, bituminous coal being worked at Yanacancha and anthracite at Punre. The province is one of exceptional mineral wealth.

F. Malaga Santolalla [§] describes the coalfields of the province of Celendin, one of the smallest but richest of the department of Cajamarca. The ore deposits are numerous, but little exploration has been carried out owing to difficulties of transport.

Coal in Chili.—The lignites occurring at Concepcion have the following average composition [||] :—

Moisture	6·74
Volatile constituents	38·96
Fixed carbon	48·29
Ash	5·99

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[*] *Foreign Office, Annual Series*, No. 3568.

[†] *Board of Trade Journal*, vol. lii. p. 82.

[‡] *Boletin del Cuerpo de Ingenieros de Minas*, Lima, No. 31.

[§] *Ibid.*, No. 32.

[||] *Revista Minera*, vol. lvii. p. 562.

III.—*CHARCOAL.*

Charcoal-burning.—Charcoal-burning in kilns is described by H. Bergström [*]; and R. Jürgensen [†] describes the continuous carbonisation of sawdust with recovery of by-products.

It is reported [‡] that the charcoal kiln erected by Holmsunds Aktiebolag, has now been completed. The chief products will be coal, tar, and turpentine. The tests have given very favourable results, and in order that all the waste material may be used up, the kiln will be kept going night and day.

According to J. Terény,[§] the demand for charcoal as fuel in blast-furnaces shows no decrease, and particulars are given of the amount of charcoal used for this purpose. The author describes the most modern apparatus for producing charcoal in retorts. The charring process employed by the Pioneer Iron Company in Michigan and by the Algoma Steel Company is described. The retorts at the last mentioned works are 46 feet long, 6 feet 3 inches wide, 7 feet 10 inches high, and contain four cars of wood, each 254 cubic feet. The Carbo Company has introduced in their works at Grötingen, Jämtland, the J. E. Aslin retort kiln. In Finland the Gröndal kiln is employed. One of the best kilns is the Ljungberg, employed at the Domnarfvet works in Sweden. It is worked in a similar manner to a Hoffmann continuous kiln. The Stora Kopparbergs Bergslags Aktiebolag have several plants on this system for their blast-furnaces. This company also employs the Heidenstam process for briquetting sawdust. The Elfström retort kiln with superheated steam, at Umea, Sweden, is also mentioned. As a rule, the retort kiln gives a more uniform charcoal and a more complete recovery of the by-products than the ordinary kiln, though the latter appears to be more economical because the fuel is better utilised and continuous working is possible. The position of the industry in Austria and Hungary is reviewed, and the author states his opinions concerning the manner in which the manufacture of charcoal in retort kilns could be carried on economically and practically.

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[*] *Bihang till Jernkontorets Annaler*, 1906, pp. 219–222.

[†] *Ibid.*, p. 222.

[‡] *Affärsvärlden*, vol. vi. p. 1101.

[§] *Banyaszati es Kohaszati Lapok*, vol. xxxix. pp. 401–417.

IV.—*COKE.*

Beehive Coke Ovens.—H. N. Eavenson [*] describes the beehive coke oven construction adopted in the Connellsville and Pocohontas coking districts. Details are given respecting block ovens and bank ovens, which differ with the varying nature of the foundations. The latter may, however, be built either back to back or "nested." The nature of the materials used, and the dimensions most commonly adopted, are described. For many years the size of the beehive coke oven has been gradually but steadily increasing, from the first ovens, 10 feet in diameter, to 12 feet 6 inches in diameter. In the Connellsville region, the Oliver No. 3 plant contains 300 ovens, each 13 feet in diameter, all built within the last three years. The United States Coal and Coke Company is now building all its new ovens 13 feet in diameter, and with the advent of the coke drawing machine, of which there are now several successful makes upon the market, it is predicted that ovens of the beehive type will be built much larger than any as yet constructed. The increase of capacity with increase of diameter of this type of ovens is much faster than the increase of the cost, and the advent of machinery will, it is hoped, do much towards solving the labour problem.

C. Eitle [†] describes a new form of coal crusher which can be adjusted to reduce coal to required sizes, and can deal with 50 tons of coal per hour, preparatory to coking.

By-Product Coke Ovens.—The new installation of by-product recovery coke ovens at Clay Cross, near Chesterfield, is described and illustrated.[‡] The plant is very well planned. The ovens are of the Simplex (Fabry-Linard) system, and the battery consists of 50 ovens, and produces 800 tons of coke weekly.

B. Dodd [§] discusses the statements of J. A. Roelofsen respecting the advantages of the Huessener coke oven. He contends that the Simon-Carvès coke ovens give as good results as any retort ovens, and that the Huessener and Solvay ovens are only modifications of this type. Comparing vertical-flued ovens with those with horizontal flues, there is little difference so far as uniform heating is concerned.

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[*] *Iron and Coal Trades Review*, vol. lxxiii. pp. 1172–1173.

[†] *Journal für Gasbeleuchtung*, 1906, p. 129.

[‡] *Iron and Coal Trades Review*, vol. lxxii. pp. 2314–2315, with five illustrations.

[§] *Transactions of the Institution of Mining Engineers*, vol. xxxii. pp. 198–201; *Times Engineering Supplement*, vol. ii. p. 303.

The quantity of by-products obtained and the ease of working depend upon the power of the plant for condensing and dealing with the gases given off, while the speed of carbonisation depends on the quality and steadiness of the condensation, and upon the regularity with which the gases return to the ovens to be burnt in the flues. The addition of gas-holders to a plant would therefore increase the ease and lessen the cost of working by equalising the pressure at the gas-burners. The yield of coke was stated to be 74·45 per cent. of the dry coal put into the ovens, but the actual result of fifty-two weeks working, during which 105,000 tons of coal were received and coked, was only 67·69 per cent. of coke containing 3·97 per cent. of moisture, or 63·72 per cent. of the coal received. Together with the coal a considerable amount of hydrogen in the form of water was introduced into the ovens, washed coal being used containing 10·6 per cent. of water; and, when this is taken into consideration, the yields do not appear any better than that of older plants.

J. Kenneth Guthrie [*] differs from Roelofsen as to the superiority of horizontal flues in by-product coke ovens. The vertical flue system also enhances the resistance of the wall, as the heating flue runs perpendicularly along all that portion of the oven wall against which the coal exerts any pressure, and the divisions between the flues forms vertical strengthening ribs. When coals of only slightly shrinking and even expanding nature are coked, as in the case of all volatile coals, this is especially advantageous. The weaker walls of horizontal flues built of hollow tiles are more apt to be crushed in by the pressure exerted by expanding coals. The vertical flue system withstands better the compression loads due to the weight of the oven superstructure, so that it is unnecessary to build supporting walls between the heating flue systems of each adjacent oven. Space is saved, and the cost of masonry, gas mains, platforms, &c., lessened.

J. A. Roelofsen [†] contests the figures Dodd gives as the actual working results of fifty-two weeks. The yield of 67·69 per cent. was calculated on the coal as it was received from the collieries and before it was washed. In calculating the yields, he only took into consideration the quantity of coal that actually came to the coke ovens. Coal charged in the compressed state by means of a charging machine gave on the whole a firmer coke than that charged by hand. In the case of coals which did not ordinarily give a very hard coke the improvement was very marked, and of great value; but with coal such as was ordinarily used at the Clarence works, which gave even with hand charging a very firm and solid blast-furnace coke, the advantages of a compressing machine were not so evident.

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[*] *Transactions of the Institution of Mining Engineers*, vol. xxxii. p. 199.

[†] *Ibid.*, p. 201.

J. Julin * describes the by-product Coppée coke ovens at the Angleur Steelworks.

O. Haarmann † discusses the outlook for the coal by-product industry. In 1904 there were in Germany 19,309 coke ovens, of which 9110 are arranged for the recovery of by-products.

F. Herbst ‡ gives an illustrated description of the Koppers coke oven. It is a modified form of the Otto oven heated from below, and has given excellent results in practice.

By-product coke ovens in America are described by E. A. Moore,§ with special reference to the Otto-Hoffman oven.

The larger place of the by-product coke oven in the United States is indicated by the record of the coke industry for 1905. From retort coke ovens the output was 3,462,348 net tons in 1905, as against 2,608,229 tons in 1904. Yet 1905 did not quite attain to the proportion of by-product coke produced in the preceding year. The percentage was 10·74, as compared with 11 per cent. in 1904, 7·4 per cent. in 1903, and 5·5 per cent. in 1902. Gauging the retort oven movement by the number of ovens building, there was a marked subsidence in 1905. Against 832 by-product ovens building at the close of 1904, out of a total of 4430 then under construction, the number was 417 out of a total of 4751 at the close of 1905.‖

H. Warth ¶ gives an account of some experiments made to demonstrate the possibility of using gypsum instead of sulphuric acid for the production of ammonium sulphate as a by-product in coke-making.

Mechanical Handling of Hot Coke.—G. F. Zimmer ** discusses the handling of coke and the substitution of machinery for hand labour at coke oven installations. The hardness, friable nature of the product, and the temperature at which it has to be dealt with present many difficulties in practice. He describes conveyors suitable for gasworks, which he believes will eventually be adopted on a larger scale at coke oven plants in the iron and steel industries. Owing to the heavy wear and tear, coke-handling appliances do not yield such good economic results as coal-handling appliances, where the conditions to be met with are less severe. He describes in detail the coke conveyors at Gaythorn, the New Conveyor Company's appliances, and those of Graham Morton & Co., Ltd., the Marshall, and the Mueller conveyors; the Bronder, West, Wild, De Brouwer, and Merz hot coke conveyors, and the Dempster hot coke conveyor.

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* *Annales des Mines de Belgique*, vol. xi. pp. 251–256.

† *Glückauf*, vol. xlii. pp. 418–433.

‡ *Ibid.*, p. 1301.

§ *Proceedings of the Engineers' Club of Philadelphia*, July 1906; *Engineering Magazine*, vol. xxxii. pp. 115–117.

‖ *Iron Age*, vol. lxxviii. p. 231; *Engineer*, vol. cii. p. 269.

¶ *Chemical News*, vol. xciii. p. 259.

** *Minutes of Proceedings of the Institution of Civil Engineers*, vol. clxiii. pp. 334–352.

F. C. Perkins * illustrates the construction of electrically-driven coke-drawing machines.

Ash and Moisture in Coke.—J. Boiteux † discusses the economic loss to blast-furnaces of coke containing comparatively high percentages of ash and moisture. With a coke containing 20 per cent. of ash and 10 per cent. of water, the loss due in handling will average 5 per cent., and such a coke will yield from 8 to 10 per cent. of coke dust. The combined losses leave no more than 650 kilogrammes of useful carbon per ton of manufactured coke. Other disadvantages resulting from the use of such a coke are as follow: (1) It is necessary to evaporate the water; (2) to extract the ash in the form of slag; (3) to use additional flux for this purpose; (4) to take into account the loss in iron due to the excess of slag; and (5) the loss in heat due to the extra weight of flux.

U. Klünder ‡ describes the behaviour of different kinds of coal when submitted to dry distillation.

Rhenish-Westphalian Coke.—F. Wüst § and G. Ott describe the results of a series of comparative tests of Rhenish-Westphalian foundry and blast-furnace coke. The German foundries pay some £60,000 a year more for their coke than is paid for a similar quantity of coke suitable for the blast-furnace, and the authors have therefore submitted the two kinds of coke to comparison, 36 samples of blast-furnace coke and 26 of foundry cokes being submitted to test. These included ash, sulphur, phosphorus, and calorific value determinations; apparent and real specific gravity;

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* *Electrical Engineer*, vol. xxxvii. pp. 768-769.

† *L'Echo de l'Industrie; Colliery Guardian*, vol. xcii. p. 512.

‡ *Montan Zeitung*, vol. xiii. p. 312.

§ *Stahl und Eisen*, vol. xxvi. pp. 841-844.

calculation of the porosity, crushing strength, and determination of the loss when ignited in a current of carbon dioxide. The methods used for these tests are given. The results showed that in the blast-furnace cokes the sulphur contents varied from 0·77 per cent. to 1·52, while in the foundry coke the limits were even greater, 0·73 and 1·58, the average for the blast-furnace coke being 1·10 and for the foundry coke 1·08. The phosphorus contents varied in the blast-furnace coke from 0·013 to 0·047, with an average of 0·022 per cent., while in the foundry coke it had exactly the same limits and also average. It was not found possible to burn the coke in the Mahler bomb completely, and the calorific value had therefore to be determined indirectly. The average for the blast-furnace coke proved to be 7058 calories, and for the foundry coke 7001. The average apparent and real specific gravities were 0·90 and 1·87 for the blast-furnace coke and 0·89 and 1·92 for the foundry coke. With regard to the porosity, that of blast-furnace coke averaged 51·34 per cent., and of foundry coke 53·34, the maximum variations for both being from 48 to 56 per cent. The crushing strength, on the other hand, varied enormously, some samples being eight times as strong as others. The densest coke has the greatest average strength and the most porous the lowest, but the separate results vary so greatly that it is impossible to deduce a true average. There is evidently no direct relation between density and strength. With reference to the loss on ignition in carbon dioxide, the authors state that the averages were 5·07 per cent. for blast-furnace coke and 4·46 for foundry coke.

The authors conclude that there is practically no difference between the two types of coke from the Ruhr district.

Ferruginous Coke.—F. Werndl * observes that the addition of fine iron ore to coal in the coking process is by no means new. It was employed by the Phœnix Works at Laar near Ruhrort on a large scale in the nineties, purple ore being used. The best results were obtained with an admixture of from 7 to 10 per cent. of the ore. The coke made was firm, and the ore in it scarcely discernible. The coke ovens used were of the Otto type, but the by-products were not collected. By-product ovens being introduced, the use of the ore was abandoned, as it was found to be accompanied by a diminution of about 20 per cent. in the quantity of benzol produced, probably due to reduction of the iron oxide in the coke.

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* *Stahl und Eisen*, vol. xxvi. p. 664.

Coke-Oven Gases.—G. H. J. Hooghwinkel * deals with the generation of electricity by the waste gases of modern coke ovens. He refers to the gas plant of the Ilseder Ironworks, which supply the necessary power to the Peine rolling-mills near Hanover. Although many coking collieries utilise the spare gases from their coke ovens under steam boilers, there are still a number of coking plants where the gases are wasted, and even in the first instance the methods employed for heating the boilers is frequently extremely wasteful. He estimates the saving which would result on the introduction of gas-engines deriving their supply from by-product ovens at 2½ millions of pounds, irrespective of the value of the by-products, which average about 4s. 6d. per ton of coal coked. The composition, calorific value, and cleaning of coke-oven gases are then dealt with. The purification of the gases is of primary importance, and nothing should be neglected to arrive at the highest degree of purity, as most of the early failures in blast-furnace and coke-oven gas plants may be traced to imperfect cleaning. The various forms of cleaning apparatus are briefly described.

W. Archer † describes two forms of dampers designed for use in the main flues conveying waste gases from coke ovens to the stack.

V.—*LIQUID FUEL.*

Origin of Petroleum.—H. Höfer ‡ discusses the origin of petroleum and of primary and secondary petroleum occurrences. Primary deposits belong to strata of pre-Cambrian age, in the deposits of which organisms must have accumulated and been transformed. Petroleum in such deposits is usually under great pressures, and hence has a tendency to deviate in various directions. Its evaporation leads to the formation of bitumen. He discusses the geology of the formations in which oil occurs, and the mode by which it accumulates under pressure in various localities.

The genesis of petroleum is discussed by P. Walden,§ who bases his views on the optical activity of vegetable matter.

C. Engler || controverts the views expressed by Walden and others as to the genesis of petroleum. He states as his conclusions that

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* *Transactions of the Institution of Mining Engineers*, vol. xxx. pp. 313–339.

† *Engineering and Mining Journal*, vol. lxxxii. p. 498.

‡ *Petroleum Review*, vol. xv. pp. 223–224.

§ *Chemiker Zeitung*, vol. xxx. pp. 391–393.

|| *Ibid.*, pp. 711–714.

petroleum is derived from the fatty matter of lower organisms after the remaining organic matter has decayed. The variety in natural petroleums is caused by the various conditions of formation (pressure, temperature, and time), and not by the nature of the fatty matter.

F. Hornung [*] deals with the question of the formation of petroleum in reference to the Permian formation of the southern and eastern borders of the Hartz.

Recent researches on the origin, analysis, and application of petroleum are summarised by R. Kissling.[†]

The genesis of petroleum is also discussed by J. Marcusson,[‡] and by A. F. Stahl.[§]

Petroleum in Germany.—The occurrence of petroleum in the Rhine Valley is described by C. Engler.[||]

The occurrence of petroleum in Alsace is described by W. Müller.[¶] Details are given of the chemical and physical properties of the Pechelbronn oil. Statistics are also given showing the rapid increase in the production from 1871 to 1904.

L. van Werveke [**] discusses the origin of the Alsatian petroleum deposits.

M. Platsch [††] gives an account of the extraction of petroleum at Wietze, in Hanover. Incidentally he mentions that endeavours are being made to institute a school for bore-masters at Clausthal.

Petroleum in Hungary.—L. Schick [‡‡] gives an account of the occurrence of petroleum in Hungary; and H. Walter [§§] describes the occurrence of petroleum at Körösmezö.

Petroleum in Roumania.—P. C. A. Stewart [||||] gives an account of the oil resources of Roumania. The oil-belt follows the outer edge of the sweep of the Carpathian Mountains, and may be regarded as a prolongation of the Galician belt. It is 300 to

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[*] *Zeitschrift des deutscher geologischen Gesellschaft*, vol. lvii. pp. 534–556.

[†] *Chemiker Zeitung*, vol. xxx. pp. 659–662.

[‡] *Ibid.*, pp. 788–789.

[§] *Ibid.*, p. 346.

[||] *Allgemeine Oesterreichische Chemiker und Techniker Zeitung*, vol. xxiv. pp. 49–50, 58–61.

[¶] *Ibid.*, pp. 65–66, 74–75.

[**] *Mitteilungen der Geologischen Landesanstalt von Elsass-Lothringen*, vol. vi. p. 30.

[††] *Chemiker Zeitung*, vol. xxx. pp. 766–767.

[‡‡] *Banyaszati es Kohaszati Lapok*, vol. xxxix. pp. 697–699.

[§§] *Organ des Verein der Bohrtechniker*, vol. xiii. pp. 37–38.

[||||] *Bi-Monthly Bulletin of the American Institute of Mining Engineers*, 1906, pp. 517–522.

400 miles in length and 15 to 20 miles wide, and is believed to cover an area of at least 59,420 acres. The primary deposits of petroleum are considered to be in the Paleogene and the Neogene. Most of the other repositories, especially those of Muntenie, are only secondary, the petroleum having been introduced by the orogeneric movements which raised the Carpathian Mountains. The oil-field has been divided by the Roumanian survey into two regions, the Flysch and the Sub-Carpathian. Numerous difficulties attend the drilling of wells, the structure being, in many cases, very complicated. The main obstacles are: water, which must be shut out, and the breaking-off (after the removal of the oil-sand by the flow of oil and gas) of a hard, highly-inclined layer immediately above the oil-sand, which causes squeezing of the casing, and a caving of argillaceous bands directly overlying the oil-sand. Where the oil is found in overturned anticlinals, there is often a slipping along lamination-planes, which results in enormous pressures on the casing. Moreover, the occurrence of quicksands, and of movements due to the removal of sand by the flowing gas and oil, may cause disaster.

F. Pavelesco [*] describes, with the aid of six illustrations, the Campina-Boushtenari-Faget-Doftanetz oil-field. Photographs of the oil workings at Baicoiu are reproduced.[†] After long-continued unsuccessful attempts to obtain satisfactory results, a spouting well of remarkable richness has been struck.

Petroleum in Canada.—R. Chalmers [‡] describes the progress made in the development of the petroleum resources of Ontario. The occurrence of oil at Petrolea, Oil Springs, and Sarnia were investigated. In the former district there are 10,000 to 11,000 wells in operation, all ending in the Carboniferous formation, and yielding on an average rather less than a barrel a day. A new oil-field is being opened up at Bothwell, Kent County, the yield being 5000 to 6000 barrels per month. The Dutton and Tilsonburg oil wells are also described.

Petroleum in New Zealand.—The occurrence of petroleum [§] near Greymouth, on the west coast of South Island, and at New Plymouth, on the west coast of North Island, New Zealand, is noted.

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[*] *Moniteur du Pétrole Roumain*, vol. vii. pp. 771–778.

[†] *Ibid.*, p. 457.

[‡] *Annual Report of the Geological Survey of Canada*, vol. xiv. pp. 160–163.

[§] *Times Financial Supplement*, June 25, 1906.

Boring operations in the latter district date back to 1865, but frequent failures occurred, notwithstanding that indications of the presence of oil were found. In 1896 a considerable flow of oil was encountered after boring to 1976 feet, but water interfered with the flow. This year, owing to the enormous pressures of gas, an abundant flow has been obtained, at a depth of 2331 feet. About 400 barrels of oil can be obtained daily.

Petroleum in Trinidad.—E. H. Cunningham-Craig * describes an oil-field in Trinidad, of at least 500 square miles, which had never been adequately tested in any part, and over a large part of this area a production of oil could be confidently expected. Much of the ground had been carefully examined, the geological structure proved, and the outcrops of the oil-bearing strata mapped. It only remained to make the actual experimental borings. Boreholes could be placed so as to strike the oil-rocks at any depth considered most convenient, but it cannot be estimated how much oil would be obtained.

E. H. Cunningham-Craig † has reported on the occurrence of petroleum in the Cedros oil-fields of Trinidad, an area of 126 square miles lying west of the Mayaro-Guayaguayare oil-field. Faults and complications are numerous, and add greatly to the difficulties of surveying the district, while the tertiary and cretaceous rocks so closely resemble each other as to enhance the difficulty of distinguishing between them. The presence of inliers of cretaceous strata probably affect the oil-field adversely. The geology of the district is described in some detail. The quality of the oil found is excellent, and the percentage of sulphur small.

R. Rust ‡ deals with the petroleum deposits of Trinidad. Explorations in the forests of the island have shown the existence of enormous deposits underlying an area of about 400 square miles, in the southern portion. One well sunk by the Canadian Oil Exploration Company, near the celebrated pitch lake at La Brea, and 40 miles from the wells sunk at Guayaguayare, furnished oil which was undoubtedly derived from the same strata, proving that the oil-sand existed in a direct line of 40 miles, at practically the same depths throughout. The quality of the oil is excellent. At one well an oil containing 32 per cent. of solid paraffin has been discovered.

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* Paper read before the Royal Colonial Institute, June 19, 1906; *Times-Engineering Supplement*, 1906, p. 195.

† *Petroleum Review*, vol. xiv. pp. 307–308, 336–337, 365–366, 393–394, 403–404.

‡ *Ibid.*, p. 293.

Petroleum in the United States.—Clifford Richardson* gives an exhaustive series of analyses of the petroleums of North America, and compares the character of those of the older and newer fields. Those of the earlier days of the industry, from the Appalachian fields, were paraffin oils, free from sulphur, specially valuable for the production of illuminants. The petroleums of north-western Ohio and Canada, next developed, being sulphur oils, were far less valuable. The California oil is composed of such a series of hydrocarbons, of a non-paraffin nature, that its value is comparatively small. The oils from the more recently developed fields of Kansas and Texas are of variable character. Those from the Gulf Coastal Plain of Texas and Louisiana are so strongly asphaltic as to be of value only for the production of lubricants, for use as fuel, and as gas-oil.

A. Vicaire † deals with the petroleum industry of the United States, which, he points out, has, as the result of a few years' development, become the most important in the world. He gives tables of the production, and classifies the output into the various commercial categories into which it falls. The occurrence of petroleum was known as far back as 1629, when the earliest Jesuit missionaries were guided to the natural wells in Ohio by the natives. Wells were found in Pennsylvania and in Canada of sufficient age for their origin to have been forgotten by the oldest natives then living, and their boring is assumed to date back to the times of the Mound Builders, who have left traces of their activity in the copper districts of the Lake Superior and elsewhere. In the succeeding years numerous sources of petroleum and of natural gas were discovered by the earlier colonists, and reference is made to a grant made in 1775 to Washington of a blower nine miles below Charleston, on the Kanawha. Various romantic finds are enumerated during the early years of the nineteenth century, but the modern history of petroleum mining in the United States dates from 1860, while the Pennsylvania oil industry dates from 1884, when large outbursts occurred in Butler County. The geological origin of petroleum is next discussed. The views of Berthelot and of Mendeléeff are considered. The latter put forward the theory in 1877 that petroleum was formed by the action of water upon metallic carbides at great depths, referring to the methods by which certain hydrocarbons were synthetically prepared in the laboratory. On the other hand, the theory which gives an organic origin to the sources of petroleum finds more numerous supporters, and the views of Sterry-Hunt, Phillips, Engler, and others are given at length. The organic origin is practically accepted unanimously by American observers. The author hesitates to adopt any of the existing theories, but considers that adhesion to the organic theory can scarcely fail to have the effect of fostering the resources, inasmuch as it would show them to be due to ephemeral causes, and would emphasise the necessity for husbanding them to the utmost. That petroleum does not exist in huge cavities in the earth's crust, but distributed in sandy and calcareous formations, the author considers proved. He next considers the causes which lead to the overflow of the pent-up oils. These he classes as (1) distillation under the influence of heat, and (2) gravity. The source of such heat as may cause a certain degree of distillation he considers to be the chemical reactions occurring naturally in the vicinity of the accumulations, such as the oxidation of organic matter and of iron sulphide, &c. The temperature at which oil-wells will be affected by these factors depends upon its constitution, and also upon the presence of impurities, such as sulphur, which raises the boiling point. The action of water as a vehicle for bringing together the oil existing in various localities and massing it in the most suitable situation is next discussed, and in this connection the geological conditions favouring the retention of the oil are considered in detail. The author then discusses the surface indications which serve to show the presence of petroleum, and deals with the association between petroleum and natural gas, and the causes which lead to natural stores of petroleum and gas collecting under pressure. The chief oil-producing districts are those considered from the point of view of their geology, beginning with the Appalachian oil area, of which maps are given, and the resources of which are enumerated in a series of tables. The Appalachian petroliferous formations include the oil-fields of Pennsylvania and New York, of Ohio, West Virginia, and of Kentucky and Tennessee. Although the oil from different fields varies somewhat in character, it remains of much the same general type of character throughout the whole Appalachian area, with the exception of certain heavy oils, such as those of Franklin or of Volcano (West Virginia), and certain wells in Kentucky. As a rule, the petroleum is a light oil, containing a large proportion of the illuminating oils.

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* *Journal of the Franklin Institute*, vol. clxii. pp. 57–70, 81–128.

† *Bulletin de la Société de l'Industrie Minérale*, vol. iv. pp. 681–849.

The next petroliferous area to be considered is the Lima-Indiana basin which extends between the States of Ohio and Indiana, and has its western border near Lake Erie, and its centre near the town of Lima. Part of this region is known as the Black Swamp. Geologically, the area is much simpler than that of the Appalachian basin, the strata preserving their original order more nearly than in the latter district. The formations are, for the most part, Silurian and Devonian, and the geology and stratigraphy are dealt with in detail. Owing to the greater porosity of the overlying strata, the oil gushes out more rapidly at first, but the supplies are exhausted sooner. Many of the oil-wells of Indiana yield a mixture of oil and brackish water, and at times the proportion of water to oil rises to 20 to 1 of the total pumped. The nature of the oil-wells in this State render it necessary to have constant recourse to shooting in order to keep up the supply. Hydrochloric acid has also been used, in calcareous soils, to widen the pipes, with very satisfactory results. The methods of boring wells and the subsequent operations and precautions to be observed in oil-mining are then discussed, and details are given of the cost of installing wells, and the charges for labour, maintenance, &c. As in the case of the Appalachian oils, the chemical and physical properties are given, together with tables showing the production.

The next oil-field discussed is that of the west, which comprises Kansas and Indian territory. The author follows the same plan as in the previous sections, and deals with the geology first. The nature of the top soils is such that seepages are common, and the saccharoid sand of the Cherokee is described in this connection.

Petroleum in Illinois.—W. S. Blatchley * has published a report, covering 109 pages, upon the petroleum industry of South-eastern Illinois.

Petroleum in Kentucky.—J. B. Hoeing † gives a statement respecting the oil and gas resources of Kentucky, with special reference to those portions of the state lying east of the Louisville branch of the railway.

Petroleum in Utah.—J. M. Boutwell ‡ deals with prospecting operations for petroleum in the Salt Lake Basin, Utah. The geology of the district is described. Numerous borings have been made, but so far the results have been meagre, although the indications of the presence of oil are plentiful. Natural gas has been discovered, but the supplies soon dwindle down. Deep borings would probably yield more remunerative results. Seepages of asphaltic matter exude in the shallow littoral portion of Great Salt Lake, and asphalt occurs in bituminous oolitic limestone, at several localities.

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* *Geological Survey of Illinois*, Bulletin No. 2.

† *Geological Survey of Kentucky*, Bulletin No. 1.

‡ *Petroleum Review*, vol. xv. pp. 63–64.

Petroleum in Asia Minor.—The various occurrences of petroleum and of asphalt in Asia Minor are enumerated by C. Schmeisser.*

Petroleum in Central Asia.—The occurrence of petroleum in Ferghana, in Russian Central Asia, is noted,† and the prospects of establishing an industry in that province discussed. Prospecting was commenced in 1900, in a concession near the Vamovskaia station of the Central Russian Railway, and in 1904 the first spouter was struck. Baling is now carried out in two wells, and eight more are being drilled. The oil does not need settling, but as the flash-point is low, it has to be treated. It possesses valuable qualities, and is equal to Baku kerosene.

Petroleum in Persia.—H. Höfer ‡ describes the petroleum resources of Persia and Mesopotamia. The oil belts are of extraordinary length, and the occurrence of oil has been known since the earliest times, being noted by Herodotus. The northern fields are situated at Hammam-Ali, on the Tigris, about twenty miles from Mosul, at Kiara, at Al-Hadhr, at El-Fatha, where petroleum and natural tar outcrop, and at Kerkuk, where there are numerous wells. Sulphur springs and bitumen deposits also occur at several of these localities. In the vicinity of Mendeli, on the Persian frontier, there were, in 1902, about thirty oil-wells in operation. The crude oil was transported in skins, by camels, to Bagdad, but has been largely superseded by American and Russian refined oil. Bitumen occurs in some abundance at Hit, on the Euphrates, where the conditions, geological and stratigraphical, resemble those of Mendeli, and on the island of Bahrein asphalt equal in quality to that of Trinidad has been encountered. The supplies have been but little developed, although certain leases have been granted, and the government also produce small quantities of oil themselves. The petroliferous region of Kend-i-Schirin has long been worked to a small extent by the Kurds.

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* *Zeitschrift für praktische Geologie*, vol. xiv. pp. 193–194.

† *Petroleum Review*, vol. xiii. pp. 507–508, 528, vol. xiv. p. 14.

‡ *Petroleum*, 1906, pp. 781–786, 819–824; *Petroleum Review*, vol. xv. pp. 147–148, 173–174.

Petroleum in China.—In the Kwantun Peninsula, near Port Arthur, a bore-hole struck, at a depth of about 1200 feet, salt water carrying considerable quantities of petroleum, of 0·8996 specific gravity, containing 1·74 per cent. of sulphur, 26·67 per cent. of kerosene, and traces of benzene. It appears to be identical with that of Baku.*

Petroleum in Japan.—I. A. Stigand † describes the occurrence of petroleum in Japan. The production of petroleum is practically confined to the province of Echigo, although smaller quantities are obtained in the provinces of Ugo, Shinano, and Totomi.

Petroleum in Sakhalin.—A. M. Ossendowsky ‡ describes the petroleum met with on the island of Sakhalin. Fractional distillation has shown it to yield :—

	Per Cent.
Benzene up to 150° C.	traces
Kerosene up to 270° C.	30·10
Pyronaphtha up to 300° C.	14·72
Mineral oil up to 360° C.	45·78
Masut residues	9·40

The deposits are very considerable, and the oil, containing no dangerous volatile constituents, is an excellent fuel for steamers. A kind of solidified oil is also found, called kyr, which forms a black elastic solid yielding on assay :—

Moisture.	Ash.	Volatile Constituents.	Ash-free Coke.
0·73	0·22	90·57	8·48

The sulphur contents amount to 2·80 per cent.

Petroleum in Sumatra.—A. Tobler § has published a topographical and geological description of the Moeara Enim oil-field in southern Sumatra. He has also published || a geological map of southern Sumatra.

Petroleum in Egypt.—J. Wells,¶ in his report on the mining industry of Egypt for the year 1905, states that on the Red Sea

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[*] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. p. 353.

[†] *Journal of the Society of Arts*, vol. liv. pp. 913–916.

[‡] *Gorny Journal*, 1905, Nos. 7 and 8; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 353–354.

[§] *Tijdsckrift van het koninklijk Nederlandsch Aardrijkskundig Genootschap*, 1906, pp. 195–315.

[||] *Verhandlungen der Naturforshenden Gesellschaft, Basel*, vol. xv. pp. 272–292.

[¶] *Board of Trade Journal*, vol. liii. p. 320

littoral, in the neighbourhood of Jebel Zeit, petroleum undoubtedly exists, but whether in commercial quantities or not is at present undecided. The concession lately held over the above area has been abandoned, but negotiations have been conducted with a view to granting other applicants the right to conduct boring operations in the neighbourhood.

Petroleum in South-East Africa.—An account is given* of prospecting operations in the Ermelo district and the Inhambane fields, which are said to present indications of vast supplies of oil. The deposits occur in shale formations. Oil likely to yield ·75 per cent. of marketable products has been found at Ermelo, where the nature of the beds is such as to favour cheap working and low cost of production. In the Nhangella Valley ozokerite and elaterite are met with in some abundance.

Asphalt.—The formation of asphalt veins is discussed by G. H. Eldridge.†

Experiments made to determine the proportion of bitumen in asphalt powder are described by D. Holde ‡ and R. Schäfer.

The relation between some physical properties of bitumens and oils is discussed by A. W. Dow.§

Clifford Richardson ‖ deals with the proximate composition and physical structure of Trinidad asphalt.

The uses of natural asphalt in the arts are enumerated by F. Lendenberg.¶

The detection of adulterants in natural asphalt is discussed by H. Köhler.**

Gilsonite of the Uintah Basin, Utah, and its mode of occurrence, are described by J. M. Pine.††

Boring for Petroleum.—R. Sorge ‡‡ urges the advantages of the flushing method of boring for petroleum.

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* *Petroleum Review*, vol. xiii. p. 501. † *Economic Geology*, vol. i. pp. 437–444.

‡ *Mitteilungen aus dem Königlichen Materialprüfungsamt*, vol. xxiv. pp. 109–114.

§ *Engineering Record*, August 8, 1906.

‖ *Ibid.*, June 30, 1906.

¶ *Scientific American Supplement*, May 5, 1906.

** *Chemiker Zeitung*, vol. xxx. pp. 673–675.

†† *Mining World*, vol. xxiii. p. 610.

‡‡ *Organ der Verein der Bohrtechniker*, 1906, pp. 217–220; *Moniteur du Pétrole Roumain*, vol. vii. pp. 739–743.

G. Olie * describes the hydraulic method of boring for petroleum in the Moreni district.

D. St. Emilian † deals with the application of electricity in boring for petroleum. Rapid progress is being made in its adoption in Roumania.

E. B. Lazarovici ‡ reviews the sanitary precautions that should be taken in boring for petroleum.

A description has appeared § of the deepest well ever drilled in America, which has been sunk by the Forest Oil Company at West Elizabeth, Pennsylvania, twelve miles from Pittsburg, to a depth of 6000 feet. At the depth of 2285 feet a flow of gas was struck which was sufficient to make steam to drill the rest of the hole. At 5500 feet the temperature was 129° F. At this depth the crown pulley broke, cut the rope, and dropped the tools 100 feet, which caused a stay of proceedings. The tools used to drill with were the ordinary size, and the approximate cost of drilling was about £8000.

J. D. Isaacs ‖ describes a method which has been adopted at the Kern River oil-fields, Bakersfield, California, for dealing with the heavy asphaltic oils obtained. The pumps deliver the oil into pipes which have been rifled in their interiors, and it is found that the whirling motion imparted to the column of oil results in the water associated with the oil being thrown against the sides of the pipe, and helping by its lubricating action to facilitate the movement of the oil in the pipes.

Uses of Petroleum.—F. Heintzenberg ¶ states that about 20 million tons of crude petroleum are sold annually, of which about one-fifth is used as fuel. The commercial advantage of oil-firing is principally in the price, and this explains the small application of oil-firing in Western Europe. In Austria, Russia, and Pennsylvania, oil and residue are used to a considerable extent for firing locomotive boilers. Oil-firing for marine boilers has considerable advantages, such as calorific value, smaller space required for stowage, fewer stokers and lighter work, easy and rapid transport, facility in regulating, burning almost without smoke, and absence of sulphur, which attacks the boiler-plates. In the following table specific gravities and calorific values of various fuels are given in British thermal units:—

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* *Moniteur du Pétrole Roumain*, vol. vi. pp. 958–960.

† *Ibid.*, vol. vii. pp. 509–511.

‡ *Ibid.*, pp. 424–426.

§ *Iron and Coal Trades Review*, vol. lxxi. p. 2027.

‖ *Engineering News*, vol. lv. pp. 640–641.

¶ *Zeitschrift für Dampfkessel und Maschinenbetrieb*, 1906, No. 16.

Fuel.	Calorific Value. British Thermal Units.	Specific Gravity.
Brown-coal	25,792	...
Bituminous coal	33,628	...
Coal-tar from Paris Gasworks	35,315	1·004
Shale oil	35,712	...
American petroleum	38,767	0·820
Light oil from Pennsylvania	39,521	0·816
Heavy oil from Pennsylvania	42,338	0·886
Light oil from Baku	45,473	0·884
Heavy oil from Baku	43,034	0·938
Petroleum from Belachany	46,623	...

J. Klaudy * summarises recent progress in the petroleum industry.

VI.—*NATURAL GAS.*

Natural Gas in Hungary.—The occurrence of natural gas in the tertiary basin of the White Körös, between Brad and Nagyhalmagy, is described by Julius Bauer.†

Natural Gas in Canada.—R. Chalmers ‡ describes the gas-fields of Ontario, in Essex and Welland counties. The former, although of limited extent, is the most productive. During the period between February 1895 and July 1901 no less than 9,639,355,000 cubic feet of gas were exported from it to Detroit alone. In the shallower wells of the Welland field the gas is said to come from the Clinton, but deep wells have yielded but little result. The resources of Thames valley, the Dunnville gas area, and Pelee Island and Hepworth are briefly discussed.

Natural Gas in Western Australia.—The occurrence of natural gas at Kalgoorlie, Western Australia, is described by E. A. Mann.§ The gas was met with at a depth of 687 feet, while sinking a diamond-drill bore-hole from the 1048 feet level. The flow of gas continued in diminishing quantity for about a month and then ceased, work being carried on meanwhile with safety-lamps.

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* *Chemische Zeitschrift*, vol. v. pp. 415–419.

† *Organ des Verein der Bohrtechniker*, vol. xiii. pp. 97–99.

‡ *Annual Report of the Geological Survey of Canada*, vol. xiv. A, pp. 163–166.

§ *Journal of the Society of Chemical Industry*, vol. xxiv. pp. 1283–1284.

Natural Gas in Kansas.—The firing of a gas-well near Caney is described by H. W. Talbot.* It was found impossible to close the well because of the high pressure, and on February 23, 1906, it was struck by lightning and ignited. After many failures it was capped on March 29, 1906, when it is estimated 3,721,000,000 cubic feet of gas had been wasted. The well is believed to be the largest natural gas-well ever drilled.

Helium in Natural Gas.—H. P. Cady † and D. F. McFarland report that the natural gas occurring at Dexter, in the State of Kansas, contains a considerable proportion of helium.

VII.—*ARTIFICIAL GAS.*

Gas Producers. — An automatic full feeder for suction gas producers is described and illustrated.‡

W. A. Tookey § deals with recent developments in the construction of suction gas producers.

O. Nagel ‖ discusses the application of producer-gases to power purposes, with special reference to the gases obtained from the Koerting producer. Both suction and pressure types are suitable for this purpose. For power plants up to 250 horse-power suction producers are recommended, while for engines of 250 to 500 horse-power pressure producers are more suitable.

The trials of gas producers,¶ mostly of the suction type, carried out at Derby, under the auspices of the Royal Agricultural Society, included installations by the following makers: The Campbell Gas-Engine Company, Ltd., Halifax; Crossley Brothers, Ltd., Manchester; Davey, Paxman & Co., Ltd., Colchester; Dowson Economic Gas and Power Co., Ltd., London; Dudbridge Iron Works, Ltd.,

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* *Engineering and Mining Journal*, vol. lxxxi. p. 945.

† *Science; Chemiker Zeitung*, vol. xxx. p. 1002.

‡ *Engineering*, vol. lxxxi. p. 285.

§ *Practical Engineer*, vol. xxxiii. pp. 589, 626, 648, 685, 714.

‖ *Engineering News*, vol. lv. p. 538.

¶ *Engineering*, vol. lxxxi. pp. 782–787, 815, with seventeen illustrations.

Stroud; Fielding & Platt, Ltd., Gloucester; E. S. Hindley & Sons, Bourton; Kynochs, Ltd., Birmingham; The Mersey Engine Works Company, Liverpool; The National Gas-Engine Company, Ltd., Ashton-under-Lyme; Newton Brothers, Derby; the Railway and General Engineering Company, Ltd., Nottingham. The producers made by these firms are described and illustrated.*

An illustrated description is given † of the plants of the Olds Gasoline Engine Works, and the American Suction Gas Producer Company, Lansing, Michigan. The producers manufactured are of the Pintsch type, and produce gas from a good grade of anthracite.

Details have appeared ‡ of the endurance tests recently carried out by R. H. Fernald on a Taylor pressure producer using bituminous coal, and a vertical three-cylinder single-acting Westinghouse gas-engine of 235 horse-power. The engine ran continuously for twenty-four days, and even at the end of that period it was not found necessary to clean it. The average full consumption was 1·39 pounds of dry coal per brake horse-power per hour.

C. Diegel § describes some types of suction gas producer. They are suitable for use with fuels yielding tarry products, and also for small coke waste. The two types described have been in use at the Julius Pintsch Works in Berlin-Fürstenwalde since 1903. The first deals with peat, brown-coal, and bituminous coal, the last-named giving a gas quite free from tar. The fuel is charged into a wide vertical pipe at the top of the producer, which, being heated all round, serves as a retort, the bituminous coal charged in at the top falling from the bottom as coke into the producer proper. To a caking coal a certain quantity of non-caking fuel should, however, also be added, to obtain good results. The second type of producer is for material in a fine state of division. It is very wide, with a step-grate, while a central take-off in the midst of the charge, surrounded by a wide free space, is provided for. Very fine coke or anthracite can be dealt with in this form of producer.

E. H. Steck ‖ describes and illustrates a suction gas producer which uses small coal. One such producer had been in constant operation at a Hanoverian works since December 1905. The coal used contained 79·37 per cent. of carbon and 10·96 per cent. of ash, with a calorific power of 7300. At the most not more than 5 per cent. extra of this small coal is used than of the anthracite nuts No. III. formerly employed, though the cost of the fine coal at the works is only 7s. per ton as against 17s. to 18s. for the anthracite. The works is provided with two such converters and the saving is estimated at £200 per annum. The gas made from the small coal contains on the average :—

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* *Engineer*, vol. ci. pp. 602-603, with six illustrations.

† *Iron Trade Review*, November 2, 1905, pp. 17–22, with thirteen illustrations.

‡ *Iron Age*, vol. lxxvii. p. 1459.

§ *Stahl und Eisen*, vol. xxvi. pp. 796–799, with three illustrations.

‖ *Ibid.*, p. 1157, with one illustration.

CO_2.	O.	CO.	H.	CH_4.	N.
4·4	0·4	22·9	19·61	1·85	50·84

and has a calorific power of about 1370. Brown-coal smalls also give good results.

The conversion of brown-coal into gas for driving motors is described by H. Neumann.[*] The extraordinary development of suction gas plants and the increase in the prices of anthracite has induced engineers to seek cheaper fuels. The greatest difficulty has been experienced in the removal of the by-products. There are two methods of attaining this object, either by using the ordinary producer and removing the tar as much as possible, or by working the producer in such a manner that the tar is transformed in the producer. The new Turk producer for brown-coal of the Gasmotoren-fabrik Deutz is an example of the first method, and with increased draught and a thick layer of fuel an efficiency of 80 to even 87 per cent. is obtained. Producers on the Blezinger system, with several thousand cleaning wires and special valves on the motor to remove the harmful tar, are working satisfactorily at Meuselwitz and Sorau. The second method of removing the tar in the producer seems to be more to the purpose, because stoppages owing to the deposit of tar in the pipes are prevented. Mention should be made of the Pintsch producer for coal or brown-coal, in which the gases containing tar are returned to the producer and burnt in the incandescent zone, and the Deutz producer, which removes the tar in a separately fixed reducing furnace coupled with the producer. The results of trials of a Deutz producer are given.

A. Blezinger[†] describes the attempts that have been made to secure the best utilisation of a poor brown-coal so as to produce continuously gas that should be suitable for heating purposes and for gas-engines. The brown-coal of Rhenish Westphalia, the author observes, contains enormous percentages of water, even up to 60, but is otherwise of excellent quality. The brown-coal the author had to deal with contained 50 per cent. of moisture, 5 per cent. of ash, and 1 per cent. or more of sulphur, chiefly in the form of pyrites. The shaft producer first employed had brick sides. These soon led to difficulties owing to the readiness with which the pyrites in the brown-coal combined with the silica. Solidified accretions formed, and these rapidly extended towards the centre of the shaft. The high contents of moisture, too, caused even the largest lumps of the coal to fall into powder, and it was found that the fuel towards the centre of the producer was often not burnt at all. This led to changes in the shape of the producer which the author describes and illustrates. Other points are also dealt with.

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[*] *Zeitschrift des Vereines deutscher Ingenieure*, vol. l. pp. 722–726, 898–903.

[†] *Stahl und Eisen*, vol. xxvi. pp. 723–731, with five illustrations.

K. Wendt * describes certain experiments made by him with a gas producer, altering the arrangements and the methods of working. He concludes that as far as producer practice is concerned, mixed gas production is always cheaper than air gas, apart also from its lower slag production. He considers, too, that for gas-engine purposes the mixed gas is the better, since in consequence of its higher contents of hydrogen it has a lower combustion temperature and a higher explosion limit when mixed with air. For use in heating furnaces he does not consider the mixed gas to be quite so advantageous, as its pyrometric effect, despite its higher calorific value, may be lower than the air gas made from the same coal. This is due to various causes: (1) It contains more water vapour than air gas, as the whole of the steam blown in has not been decomposed; (2) the combustion temperature of hydrogen, despite its higher calorific value, is lower when burnt with air than is that of carbon monoxide; and (3) the author feels by no means sure that the calorific value of the hydrogen after its great pre-heating in the regenerative furnace, is the same as that resulting from its combustion with air at ordinary temperatures, since steam more readily decomposes than does carbon dioxide, especially by contact with molten steel at high temperature. It is rather, therefore, when the fuel to be used in the producer contains but little volatile constituents, that mixed gas is to be recommended for use in heating furnaces. Under suitable conditions producers may be made to produce a mixed gas of higher calorific power than ordinary air gas. It is better to modify the shape of the producer than to blow in too much steam, if it is a question of reducing the quantity of slag produced.

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* *Stahl und Eisen*, vol. xxvi. pp. 1184–1191, with six illustrations.

Power-Gas.—O. Nagel * deals with the advantages attending the use of gaseous fuels. He classifies them into two groups, according as they have been obtained by dry distillation, or by the incomplete combustion of coal. A third grouping contains gases derived from the action of water on carbides. In the first category he places gases obtained from coal, peat, wood, fat, and oil residues, and in the second producer-gases, blast-furnace gases, air and steam gases, such as Dowson gas, and air and carbon dioxide gases, or regenerated combustion gases. He gives tables showing the composition of the above gases, and details the precautions to be observed in endeavouring to secure theoretical perfection in their production.

J. Bueb † deals with the manufacture of gas in vertical retorts. Each furnace contains ten retorts 13 feet long, placed vertically in a chamber which is heated by gas from a producer fed with coke on one side and burned by air. The coke consumption is about 14 per cent. of the weight of the coal distilled.

M. Chikashige ‡ describes the application of carburetted water-gas as a fuel in laboratory operations, with special reference to its action when employed in the Bunsen burner. The orifice of the burner requires to be enlarged to allow of the passage of a greater volume of gas than in the case of coal-gas. The action of the gas is not more injurious to copper, porcelain, or platinum vessels than that of ordinary gas, nor are its effects on the atmosphere any worse.

C. Eberle § and A. Zschimmer review experiments to determine the loss due to unconsumed furnace-gases. Experiments were made in 1879 and 1880 by Bunte, and it was found that with Saar coal, with the draught properly regulated, the loss was only from 1 to 2 per cent., but when the draught was not properly regulated this loss rose to 15 per cent. With Ruhr coal the loss amounted to from 2 to 5 per cent. and rose to 20 per cent. These losses are considerably greater with Bohemian and Bavarian coals. The Bayerischer Verein made extensive experiments with coals of various countries and with different kinds of grates. The proportion of volatile to fixed carbon has special influence; brown-coal with a proportion of 2·1 gave a loss of 26 per cent. when burnt on an ordinary grate, which was reduced to 5·8 per cent. when the brown-coal was mixed with two-thirds Ruhr coal.

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* *Electrochemical and Metallurgical Industry*, vol. iv. pp. 403–408.

† *Zeitschrift des Vereines deutscher Ingenieure*, vol. l. pp. 198–202; *Engineer*, vol. ci. p. 383.

‡ *Journal of the Society of Chemical Industry*, vol. xxv. pp. 155–156.

§ *Zentralblatt für Eisenhüttenwesen*, vol. i. p. 473.

The ordinary grate gave the worst results for coals with large quantities of volatile carbon. With a well-constructed grate even with a slight excess of air a very good utilisation of the fuel may be obtained. For testing the flue gases to ascertain the quantity of unburnt gas a special apparatus is necessary. This apparatus is described and explained with the aid of drawings.

Gas-Engines.—Progress in the construction of large gas-engines is reviewed by H. Bonte.*

An illustrated description of an improved form of the Körting gas-engine has appeared.†

E. Freytag ‡ describes the gas-engines shown at the Milan Exhibition.

Horace Allen § deals further with modern gas-engine practice

Gas Turbines.—L. Sekutowicz ‖ deals exhaustively with the theory, design, and construction of gas turbines. He begins by defining the gas turbine, and traces the history of the progress of the turbine from the earliest inception of the idea of employing gases in such engines. He then investigates the thermo-dynamics of gas turbines, their mechanical efficiency, and the various cycles which can be adopted in gas turbine practice. The mathematical considerations involved are then discussed, and the design and construction of gas turbines dealt with in detail. A bibliography of the literature is given. He classifies turbines as those employing the Carnot cycle; and those using an isobaric cycle, which involves isothermic compression carried up to 30 or 40 atmospheres, rejecting adiabatic compression. A third cycle is an isopleric cycle, which is a cycle of constant volume. The last two cycles correspond to the combustion and explosion motors respectively. Producer-gas, waste gases from blast-furnaces, coke-oven gases, and indeed all fuels of a similar description are available for driving gas turbines when introduced, under pressure with air, into a combustion chamber sufficiently large to secure complete combustion before delivery from the expansion nozzle. The latter is subject to high stresses and temperatures, and carborundum is used for the purpose. For the turbine wheel itself, which has to be of a material the tensile strength of which is not materially diminished by the high temperatures (500 to 600° C) at which it has to work, nickel steel is suggested, as it is able to withstand the oxidising influence of the stream of heated gases.

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* *Zeitschrift des Vereines deutscher Ingenieure*, vol. l. pp. 1249–1257.

† *Engineer*, vol. ci. pp. 498–499, with five illustrations.

‡ *Dinglers Polytechnisches Journal*, 1906, pp. 614–617.

§ *Mechanical Engineer*, vol. xvii. pp. 7, 41, 93, 112, 162, 194, 211, 263, 308, 341, 371, 411, 429, 464, 500, 551, 583, 632, 655, 666, 704, 717, 759, 803, 823, 860, 896.

‖ *Mémoires de la Société des Ingénieurs Civils*, 1906, No. I. pp. 195–302.

J. Deschamps* also deals with the future prospects of the gas turbine.

F. W. Burstall† deals with some future developments of the heat engine and incidentally discusses the prospects of gas turbines.

A. Berthier‡ discusses the theory and practice of gas turbines.

C. E. Lucke§ also discusses the use of the gas turbine and describes tests of its efficiency. He gives the opinions of a number of eminent engineering authorities, and concludes that the difficulties which exist in the way of its progress and development are very great and that a practical gas turbine is still a thing of the future.

VIII.—*COAL-MINING.*

Search for Coal.—The difficulties encountered in trying to bring up a perfect core in boring for coal with a diamond drill in British Columbia are recorded by R. C. Campbell-Johnston.||

Shaft-Sinking.—O. Wex¶ describes the plant installed in the Rhenish-Westphalian collieries during the past year. The deepest shaft in the field is that of the Werne colliery with 850 metres. Great depths have also been reached by other collieries: General Blumenthal (841 metres), Ewald (742 metres), Hansa (720 metres), and Schlägel und Eisen (700 metres). The deepest shaft in Germany is at Morgenstern colliery, Zwickau, Saxony (1028 metres), and in Belgium and probably in Europe, the Produits colliery at Flénu (1161 metres), with workings extending to 1196 metres. The author also enumerates the steam-turbines, waste-steam-turbines and gas-engines installed at Rhenish-Westphalian collieries.

Recent methods of shaft-sinking as exemplified at the Exhibition at Liége are figured and described by A. Habets.** Amongst the

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* *Mémoires de la Société des Ingénieurs Civils*, 1906, No. I. pp. 304–316.

† *Journal of the West of Scotland Iron and Steel Institute*, vol. xiii. pp. 98–110.

‡ *Génie Civil*, vol. xlviii. pp. 72–74.

§ *Engineering Magazine*, vol. xxxi. pp. 641–656.

|| *Mining Journal*, vol. lxxx. pp. 96–97.

¶ *Glückauf*, vol. xlii. pp. 1337–1345.

** *Revue Universelle des Mines*, vol. xii. pp. 230–260.

methods dealt with are sinking, with the simultaneous use of cement for the walls, and the new Frich and Nöllenburg process, which is a rival of the Kind-Chaudron system. The large borer of the latter system is replaced in the Frich and Nöllenburg system by a multiple system of smaller borers. The advantages of this method over the older Kind-Chaudron method are described in detail.

Wewetzer* gives a detailed account of the sinking of the Julius shaft of the La Houve Coal Company at Kreuzwald in Lorraine, by the Kind-Chaudron process. Boring was begun on January 4, 1900, and completed on December 18, 1900, when the shaft had obtained a depth of 105·9 metres. The tubbing and concreting was completed by April 1901. Difficulties with water were encountered, and it was found necessary to continue the sinking, and it was not until 1904 that the Julius pit reached a depth of 117·10 metres, 2¾ years being devoted to dealing with the access of water.

E. Harzé † describes the sinking of shafts through quicksands and water-bearing strata by caisson sinking.

A. E. Hartmann ‡ describes the Honigmann method of shaft-sinking through quicksands. In this method no casing is built until the shaft has been completely sunk through the sand to solid rock. To prevent caving-in the water-level in the shaft is raised to a certain height above the natural level in the sand, and the specific gravity increased to about 1·2 by mixing clay with it. By these means a pressure is obtained which forces the clay into the shaft walls, thus making a more solid mass.

H. J. Joosten § describes the sinking of two shafts by the freezing process at the Dutch government colliery (Wilhelmina mine) in the province of Limburg.

H. J. Joosten ‖ traces the development of the freezing process of shaft-sinking since its introduction in 1883. He gives detailed particulars of the ninety-three shafts sunk by this method.

F. Drobniak ¶ gives a detailed description of the sinking of a shaft by means of the Poetsch freezing process at Brzeszcze.

W. Philippi ** describes the electrically driven sinking plant at the

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* *Glückauf*, vol. xlii. pp. 807–811.

† *Revue Universelle des Mines*, vol. xiv. pp. 101–113.

‡ *Engineering and Mining Journal*, vol. lxxxi. p. 751.

§ *Glückauf*, vol. xlii. pp. 577–584.

‖ *Ibid.*, pp. 703–724.

¶ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 357–362, 378–380, with two plates.

** *Elektrotechnische Zeitschrift*, vol. xxvii. pp. 806–812.

Wilhelmina colliery, Heerlen, Holland, and points out its advantages over steam plant.

C. Coryell * describes the sinking of a shaft through water-bearing strata by the aid of steel sheet piling at the Auburn shaft of the Robert Gage Coal Company, Bay City, Michigan. The method employed for driving the piles at the bottom of the shaft was of special interest. At the surface, and near the top of the shaft, was a Star drilling machine handling a 1600 pound hammer by means of a jerk line, and giving it about 3 feet of drop. It was guided by a system of sheaves, directly over the piling, with the addition of a large piece of pipe made of heavy sheet steel. In the shaft itself, Friestedt interlocking steel piling was employed.

The Zulma-Blanchet pneumatic system of shaft-sinking is described by G. Blanchet † in continuation of the earlier descriptions contributed by his father. He gives details of the calculations required to ascertain the length of tubing, the diameter, thickness of the walls, power consumption, and pressures of working necessary to the successful working of the system.

Explosives in Collieries.—G. Chesneau ‡ has completed his report on the results obtained at the Frameries station for the testing of safety explosives.

Electricity in Mines.—S. F. Walker § deals with the subject of earth in collieries with reference to the special rules for the installation and use of electricity issued by the Departmental Committee. Earth must be represented by a conductive path and very low resistance. With such a path in dry and dusty mines leakage recorders will only work if the cable makes actual connection with the metal used for earth. He deals in detail with the rules referring to connections to earth.

G. Baum,‖ in an important series of articles on power production at mines, refers to a paper read at Glasgow by G. T. Beilby, and expresses the opinion that the long distance electric transmission of power is, in Great Britain, of more importance than in Germany. The greatest tension attained in Germany, 30,000 volts at the Urftal

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* *Engineering News*, vol. lv. p. 296.

† *Bulletin de la Société de l'Industrie Minérale*, vol. iv. pp. 1181–1248.

‡ *Annales des Mines*, vol. viii. pp. 407–419.

§ *Transactions of the Institution of Mining Engineers*, vol. xxx. pp. 404–428.

‖ *Glückauf*, vol. xlii. pp. 1137–1155.

Central Station, has been far exceeded in America. The Ontario Power Company has a transmission for 258 kilometres at a tension of 60,000 volts.

C. V. Allen [*] discusses the application of electricity to mining.

S. T. Boam [†] deals with the installation and working of electric plants at collieries in connection (1) with the generation of steam and the selection and construction of the engine; (2) the choice of the dynamo, and the selection of three-phase versus continuous current; (3) the distributing system; (4) the motors and the machines they drive; and (5) the results attained in the practical working.

A description and illustrations of the electric installation at the shale mine and oil works of the Pumpherston Oil Company in Midlothian have been published.[‡] In the engine-house there are two main generators consisting of two Willans and Robinson 1000 horse power 3-throw triple expansion engines. The alternators have stationary armatures and revolving fields, and are designed to give 750 kilovolt-ampères of three revolutions per minute, the voltage being 480. The sinking pump is designed to lift 110 gallons of water per minute against a head of 180 feet. The haulage plant is well planned, the shale being conveyed to the works by a motor-driven endless rope haulage system, and unloaded on to tip waggons. Three sets of motors have been installed. The total cost of the installation has been £17,000.

Electrical installations in mines and collieries are described by A. Halleux.[§]

M. Orban [‖] gives a detailed description of the generating station and electrical equipment at the Hasard colliery, Belgium.

Compressed Air in Mines.—The use of compressed air in the mines of the Pittsburg Coal Company is described by R. S. Moss.[¶]

The uses of compressed air in coal-mines are discussed by J. L. Dixon.[**]

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[*] *Engineering Magazine*, vol. xxxi. pp. 668–690.

[†] Paper read before the National Association of Colliery Managers; *Iron and Coal Trades Review*, vol. lxxii. pp. 1313–1314.

[‡] *Engineer*, vol. ci. pp. 366-368, with six illustrations.

[§] *Annales des Mines de Belgique*, vol. xi. pp. 99–110.

[‖] *Bulletin de la Société Belge d'Electriciens*, vol. xxiii. pp. 185–219, 224–261.

[¶] *Mining World*, vol. xxiv. pp. 694–695, with four illustrations.

[**] *Mines and Minerals*, vol. xxvii. pp. 83–85.

Rock Drills in Collieries.—Norman Nisbet [*] shows by comparative tests that there is a material saving by using the air drill as against hand-power. The particulars given refer to a stone-drift in the Houghton colliery.

Coal-Cutting Machinery.—The reports of H.M. Inspector of Mines [†] show that the use of coal-cutting machinery in British collieries continues to increase. In 1903 there were in use 643 machines, 755 in 1904, and 946 in 1905. These 946 machines produced 8,000,000 tons of coal, and as the total output of Great Britain was 236,000,000, there is still a wide field open for the introduction of coal-cutting machines. Of the machines in use, 500 were driven by compressed air and 446 by electricity.

L. Tübben [‡] gives a detailed account of the coal-cutting machines in the collieries of the Ruhr, North France, and England.

The behaviour of the Ingersoll-Sergeant impact pneumatic cutter is described by Lançon. [§]

The coal-cutting machines shown at the recent Exhibition at Liége are figured and described by A. Habets. [||]

A. Pigeot [¶] describes the mining appliances shown at the recent Exhibition at Liége. The appliances enumerated comprise, in addition to coal-cutting machinery, winding-engines, pumps, air compressors, lighting and ventilating plant, fire-damp indicators and safety-lamps, and surface appliances for handling, washing, and screening coal. He concludes with the principal exhibits of life-saving apparatus for work in fiery mines.

F. W. Parsons [**] gives details of the cost of machine-mining of coal in the Pittsburg seam, Pennsylvania, where each machine will produce about 50 tons per eight hour day, cutting 65 feet of face to a depth of 5 feet.

C. E. Watts [††] gives an account of improvements made in coal-mining practice in the bituminous collieries in Pennsylvania. The installation of improved machinery, and particularly the extended use of coal-cutting machinery, has caused a remarkable increase in production.

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[*] Paper read before the National Society of Colliery Managers, July 25, 1906; *Mining World*, vol. xxv. p. 237; *Iron and Coal Trades Review*, vol. lxxiii. pp. 588–859.

[†] *Mines and Quarries: General Report and Statistics*, Part II.—Labour, p. 109.

[‡] *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. liv. pp. 321–362.

[§] *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1905, pp. 238–241.

[||] *Revue Universelle des Mines*, vol. xii. pp. 227–230.

[¶] *Bulletin de la Société de l'Industrie Minérale*, vol. iv. pp. 1037–1125.

[**] *Engineering and Mining Journal*, vol. lxxxii. p. 304.

[††] *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xxi. pp. 487–507.

Mine Supports.—R. Hundt * describes the replacement of timbering by reinforced concrete in the Wilhelm shaft of the König colliery, Saarbrücken.

F. Seidenschnur † has an article on the impregnation of mine timber, in which he summarises the results obtained in Upper Silesia.

Methods of Working.—F. C. Swallow ‡ describes coal-mining practice as carried out in Staffordshire and Worcestershire, with special reference to the difficulties met with in South Staffordshire in respect to the unwatering of the mines.

Some notes on the equipment of the Bargoed colliery of the Powell-Duffryn Company are given by E. M. Hann.§

The water-flush method of packing is described by H. Schmerber.||

R. Hundt ¶ describes the applicability of the water-flush method of packing to the ordinary processes of working in vogue in the Ruhr coalfield.

F. Busson ** describes the method of working in vogue in the Voitsberg-Köflach brown-coal district, Austria.

Hydraulic packing and its application in French collieries are described by de Renéville.††

The final section ‡‡ of the report of the Prussian Commission on Falls of Stone and Coal has been issued. It contains reports on the flushing method of stowing colliery workings by Dobers, Kaltheuner,

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* *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussichen Staate*, vol. liv. pp. 315-321.

† *Glückauf*, vol. xlii. pp. 560-563.

‡ Presidential address before the South Staffordshire, Warwickshire, and Worcestershire branch of the National Association of Colliery Managers; *Iron and Coal Trades Review*, vol. lxxii. pp. 1260-1261.

§ *Proceedings of the Institution of Mechanical Engineers*, July 30, 1906.

|| *Génie Civil*, vol. xlix. pp. 57-59, 68-71.

¶ *Glückauf*, vol. xlii. pp. 873-879.

** *Berg- und Hüttenmännisches Jahrbuch der k. k. Montanistischen Hochschulen*, vol. liv. pp. 99-166.

†† *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1906, pp. 100-102.

‡‡ *Die Verhandlungen und Untersuchungen der preussischen Stein- und Kohlenfall Commission*, Part VII. pp. 621-690. (Berlin: W. Ernst & Son.)

and M. Mengelberg, and on systematic timbering by Kaltheuner, Klose, and M. Mengelberg.

W. Arbenz * gives an exhaustive account of the water-flush method of stowing at the Kōnigin Luise colliery at Zabrze in Upper Silesia

Bodifée † describes the method of working adopted at the Monopol-Grillo colliery.

The most important undertaking in the way of submarine mining on the North American Continent is that of the Princess coal-mine of Nova Scotia. At this mine coal of an average thickness of seam of 6 feet is worked at a distance of 5800 feet from the shore. The under-sea workings cover 1620 acres, and at their furthest point are 1180 feet below sea-level, the water being 40 feet deep at this place. At the shore-line the cover is some 690 feet, but parts of the workings are carried on under a cover of only 500 feet. Practically no sea-water has found its way down to the workings as the result of removing the pillars; the cause of this, it is supposed, is to be found in the fact that beds of fireclay of an aggregate thickness of some 39 feet, and also beds of shale, form part of the superincumbent strata.‡

A new method of coal-mining is described by C. Dixon,§ and mining methods in the Western Interior coalfields are described by W. R. Crane. ||

G. Rez ¶ has an illustrated article on the Pennsylvania coal-mining industry.

F. W. Parsons ** describes the method of working coal by open stripping in the Hazleton district, Pennsylvania.

A description is given by R. S. Moss †† of the Chicago and Big Muddy Coal and Coke Company's mines, Williamson County, Illinois.

In Central and Eastern Pennsylvania there are many beds of anthracite at only a shallow depth below the surface, from 10 feet to 50 feet, and the working of these was in the past a matter of some difficulty. Such depths as these are difficult to mine safely and require a lot of timbering, which, growing more expensive each year

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* *Glückauf*, vol. xlii. pp. 606–632.

† *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. liv. pp. 305–307.

‡ *Engineering and Mining Journal*, vol. lxxxii. p. 354.

§ *Mines and Minerals*, vol. xxvii. pp. 32–35.

|| *Ibid.*, pp. 26–27, 91–94.

¶ *Banyaszati es Kohaszati Lapok*, vol. xxxix. pp. 443–453.

** *Engineering and Mining Journal*, vol. lxxxi. pp. 1239-1240.

†† *Mining World*, vol. xxiv. pp. 213–214.

in the United States, is a serious consideration. For some four years these difficulties have been overcome by the use of a steam-shovel for stripping the overburden. This process has proved most successful, resulting in the working of large beds of anthracite, which would otherwise have had to remain undeveloped.*

J. J. Rutledge† describes recent improvements in colliery practice in Illinois. The panel system has, to a large extent, superseded the pillar-and-stall methods hitherto employed at the largest collieries.

Underground Haulage.—S. Hare‡ contributes notes on top and bottom endless rope haulage on curves as practised at Bedlington colliery, Northumberland.

W. Maurice§ describes the Rateau exhaust steam three-phase haulage plant installed at the Hucknall Torkard colliery, Nottingham.

F. W. Parsons‖ describes the construction of colliery stables, and gives dimensions for stalls and partitions, and hints as to lighting, storage of forage, and cleaning.

The types of electric mining locomotives employed in Great Britain are described by J. F. Gairns.¶

The various tipping arrangements for colliery waggons are described by T. Campbell Futers.**

Haulage in mines in Alabama is described by W. R. Crane.††

The latest developments in electric mine haulage are noted,‡‡ with special reference to electric mine locomotives.

Colliery Chains.—W. Macpherson§§ discusses the construction, use, and upkeep of chains in use in collieries, with special reference to the detection and arrest of deterioration. He classifies the various types of links adopted, and shows for what special form of work they are best adapted. He also gives hints as to the testing of the strength of welds.

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* *Railway Gazette; Engineering*, vol. lxxxii. p. 328.

† *Mining Magazine*, vol. xiii. pp. 183–189.

‡ Paper read before the National Association of Colliery Managers, August 6, 1906; *Iron and Coal Trades Review*, vol. lxxiii. p. 588.

§ *Page's Weekly*, vol. viii. p. 1395.

‖ *Engineering and Mining Journal*, vol. lxxxi. p. 745.

¶ *Ibid.*, vol. lxxxii. pp. 15–17, with six illustrations.

** *Colliery Guardian*, vol. xcii. p. 399.

†† *Mining and Scientific Press*, August 25, 1906.

‡‡ *Engineering and Mining Journal*, vol. lxxxi. pp. 1241–1242.

§§ Paper read before the National Association of Colliery Managers, March 17, 1906; *Iron and Coal Trades Review*, vol. lxxii. pp. 1311–1313, with six illustrations.

Winding-Engines.—K. J. Müller * deals with the control of steam winding-engines.

The frictional resistance between the winding-rope and the driving-pulley, and the choice of the diameter of the pulleys in the Koepe system, are described by Liebe. †

Seidl ‡ deals with the use of the flat rope in the Koepe system of winding.

A. Liénard § discusses electric winding-engines. He classifies them into three groups, (1) alternating current machines, (2) machines employing either alternating or continuous currents, and (3) machines requiring continuous currents. Although strictly speaking this division is arbitrary, it is convenient in practice. Dealing with engines of the first class, he describes the installations at the Preussen II. pit of the Allgemeine Electricitäts Gesellschaft, and those at the Grand Hornu collieries, Mons. The Ilgner and Créplet systems are also discussed. The third category is exemplified by the plant installed at a number of French and German collieries.

P. Habets || summarises the results obtained in practice with electric winding-engines, and compares the behaviour of the principal types of such engines now on the market. He gives a list of machines built by the Allegemeine Electricitäts Gesellchaft, the Lahmeyer Company, the Siemens-Schuckert Werke, and the Compagnie Internationale d'Electricité.

The use of steam and of electricity for winding-engines is discussed and compared by Wallichs,¶ who concludes that neither possesses conclusive general advantages over the other, but that the circumstances must decide which is the better to be employed.

A. Gradenwitz ** describes the electric hoisting installation at the Noel-Sart-Culpart collieries, Gilly-les-Charleroi, Belgium.

The electric winding-engine at Karwin is described and illustrated by K. Ilgner.††

New installations of electric winding plant at the Gisela shaft, Dux, and at the Salomon shaft, Moravian Ostrau, are described by K. Ilgner.‡‡

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* *Glückauf*, vol. xlii. pp. 558–560. † *Ibid.*, pp. 1047–1049.

‡ *Ibid.*, pp. 910–911.

§ *Bulletin de la Société de l'Industrie Minérale*, vol. iv. pp. 1127–1179.

|| *Revue Universelle des Mines*, vol. xv. pp. 1–33.

¶ *Stahl und Eisen*, vol. xxvi. pp. 751–754, with five illustrations.

** *Engineering and Mining Journal*, vol. lxxxi. pp. 1095–1098.

†† *Elektrotechnik und Maschinenbau*, Vienna, vol. xxiv. pp. 681–686.

‡‡ *Ibid.*, pp. 701–706.

Drawings have been published of an 85 horse-power electric winding-engine for the Lens colliery, France.*

Damm † gives an illustrated description of the electrically driven winding-engine at the Ligny-les-Aire collieries. The electric winding plant is installed directly above the shaft aperture. It raises 105 tons per hour from a depth of 400 metres, and has been in operation since November 1905 without intermission.

Winding Appliances.—H. Undeutsch ‡ considers safety catches, pointing out that these are very liable to failure in one way or another, and referring to experiments of his own which dealt with this subject. The question is to some extent considered mathematically.

E. Ferraris § describes the Undeutsch safety catch for mine cages. It has four chief features: (1) The brake proper, consisting of thin adjustable knife edges fastened to the cage, and so arranged that when the rope breaks they not only grasp the wooden guides but cut into them as well; (2) the motive apparatus; (3) the safety appliance, consisting of lugs attached to the cage itself; and (4) the regulating appliances. The theoretical considerations upon which the efficiency of the catch is based and taken in detail, and the results which have been achieved in practice, are described.

The principles of the design and construction of the Hanley safety appliance for cages is described. ||

An illustration has been published ¶ of the pithead frame for the Béthune collieries, France. The shaft has two cages carrying twelve ½-ton trucks.

E. Brandi ** describes modern types of large mine head frames, with special reference to those installed at German collieries.

W. Waplington †† gives a description and design of the best arrangement and equipment of the bottom, within a radius of 400 yards, of a pair of pits to be upcast and downcast respectively.

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* *Engineering*, vol. lxxxi. pp. 644-645, 654.

† *Glückauf*, vol. xlii. pp. 1201-1215.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 105-109, and 122-127.

§ *Engineering and Mining Journal*, vol. lxxxi. p. 998-1000.

|| *Iron and Coal Trades Review*, vol. lxxiii. pp. 117-118.

¶ *Engineering*, vol. lxxxii. p. 235.

** *Mining Magazine*, vol. xiii. pp. 392-398.

†† *Proceedings of the South Wales Institute of Engineers*, vol. xxiv. pp. 580-594, with plate.

Winding-Ropes.—G. Ryba [*] discusses the wear of winding-ropes.

H. Kroen [†] discusses the safety of wire ropes that are to be used for cages. This is a further consideration of the same subject dealt with by him previously. [‡] The question of the permissible degree of fracture of the individual wires without the safety of the rope itself being endangered is discussed. The subject is again dealt with mathematically.

During the year 1905 the wire ropes replaced in the Breslau mining district [§] numbered 192, only one of which fractured while in use—a reduction of 94·59 per cent. since 1882. This great reduction is due to iron wire ropes not being employed at all, and band steel ropes but rarely. Better wire, too, has been used of late years for the round ropes. The ordinary crucible steel wire, having a tensile strength of 76 tons per square inch, is now rarely used in Upper Silesia for wire ropes, the wire used being generally of patent crucible cast steel and with tensile strengths of 95, 114, or 207 tons per square inch. Plough steel wire of the latter strength is only used in a few instances.

Mine Drainage.—Kegel [‖] gives details of the inflow of water in the collieries of the Ruhr coalfield.

G. H. J. Hooghwinkel [¶] discusses the application of electric pumping at collieries. The latest electrically driven mining pump, which is of the high-pressure centrifugal type, he deals with at length on account of its cheapness, small dimensions, strong construction, and ability to pump dirty water, together with the small compass into which it can be packed. Where existing slow-speed steam pumps are converted into electrically driven pumps, special motors must be built. He gives an account of a pumping plant at the Bliesenbach colliery, and at the Victor Rauxel and the new Iserlohn collieries in Germany.

A report is published [**] of trials with electric pumping at the Francisca colliery, near Witten. The loss was 33·58 per cent., and the total efficiency 66·42 per cent.

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[*] *Zeitschrift des Verbandes der Bergbau Betreibsleiter*, 1906, pp. 145-154.

[†] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 145–148.

[‡] *Journal of the Iron and Steel Institute*, 1905, No. II. p. 623.

[§] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 425–428.

[‖] *Bergbau*, September 27, 1906.

[¶] *Transactions of the Institution of Mining Engineers*, vol. xxix. pp. 636–653.

[**] *Glückauf*, vol. xlii. pp. 1269–1282; *Zeitschrift des Vereines deutscher Ingenieure*, vol. l. pp. 1574–1582.

F. C. Perkins* describes the electric pumping plant at the Delaware, Lackawanna, and Western anthracite mine. It raises 4000 gallons of water per minute to a height of 550 feet.

F. Trippe † shows that the draining of porous strata is the cause of subsidence in the Rhenish Westphalian coal-field.

Mine Ventilation.—T. H. Johnson ‡ advocates the employment of centrifugal fans of the Ser type. Compared with the Guibal fan, he claims for the former absence of interference at the intake, a large number of vanes and avoidance of eddies, and the curved form of the vane, which enables it to discharge the air more nearly in a tangential direction.

Henri and Léon Bochet § discuss the results of an elaborate series of experiments made on a Capell fan. The net efficiency they found to be about 60 per cent. as a maximum, but it also appeared that if the kinetic energy of the air at certain points of its path were measured, the apparent efficiency exceeded unity, and might reach nearly 1·67. The explanation is, of course, to be found in the laws governing the flow of a fluid through a channel of varying section. If water flows through a converging-diverging nozzle, its velocity head at the throat may be much greater than the total nominal head-producing flow. Incidentally they noted that the coefficient of contraction for a jet of air flowing through an orifice in a thin wall was not independent of the size of the openings, being about 0·80 when the area of these is about 15·5 square inches, diminishing to about 0·40 for extremely small openings.

J. R. Robinson ‖ describes a modern mechanical mine ventilator.

Breyhahn ¶ describes a new apparatus for controlling mine ventilation.

A. Gradenwitz ** describes the electrically driven ventilating plant at the Northberg mine in Germany.

Schmitz †† describes the system of ventilation in use at the Neumühl colliery.

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* *Mining World*, vol. xxv. p. 400.

† *Glückauf*, vol. xlii. pp. 545–558.

‡ *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xxi. pp. 390–404.

§ *Comptes Rendus*, vol. cxlii. pp. 990–992.

‖ *Mining World*, vol. xxv. pp. 156–157.

¶ *Glückauf*, vol. xlii. pp. 1345–1351.

** *Engineering and Mining Journal*, vol. lxxxii. pp. 63-65.

†† *Bergbau*, August 30, 1906.

W. B. Snow * deals with the design of fan-blowers, and discusses the application of electricity to such blowers.

Gases in Mines.—C. Latham † contributes notes on the detection and estimation of inflammable gases in mines by means of flame caps. He deals with the Courrières mining disaster, and summarises the results of several Royal Commissions on coal-dust explosions. He points out that the terms "flameless" and "safety" should not be applied to permitted explosives, and that it cannot be too strongly impressed upon users of such explosives that all that can be claimed for them is a reduction in the time during which the flame is in existence compared with unpermitted explosives. He enumerates the conditions which require to be fulfilled in order to render gas-testing apparatus of practical value. The flame-cap type of indicators more nearly fulfil the necessary requirements, and possess the additional advantages of not rendering any further apparatus necessary, and not requiring any special training in order to make it of use to the unskilled miner. He then describes in detail the Pieler and Chesneau alcohol testing flame, the Ashworth benzoline testing flame, and the Mallard and Le Chatelier hydrogen testing flame. The Clowes modification of the latter can detect 0·5 per cent. of inflammable gas without difficulty. The Beard-Mackie indicator is also described.

R. McLaren ‡ describes the new McCutcheon patent fire-damp detector, which differs radically from the usual form of fire-damp detectors, and is not a lamp. It works on the principle of diffusion, and has indicated the presence of 0·15 per cent. of fire-damp in the atmosphere.

H. Hoffmann § gives the results of tests at Gelsenkirchen with fire-damp, and with the protection of electric machinery for fire-damp.

Mine Explosions.—J. T. Beard || deals with the causes which influence and determine explosions in mines, from notes made on the occasion of an explosion at No. 2 mine of the Crow's Nest Pass

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* *Cassier's Magazine*, vol. xxix. pp. 219–229, with ten illustrations.

† *Transactions of the Institution of Mining Engineers*, vol. xxxi. pp. 136–149.

‡ *Transactions of the Mining Institute of Scotland*, vol. xxviii. pp. 157–165; *Iron and Coal Trades Review*, vol. lxxii. pp. 2317.

§ *Zeitschrift des Vereines deutscher Ingenieure*, vol. l. pp. 433–441, 487–496.

|| *Engineering and Mining Journal*, vol. lxxxi. pp. 952–955.

Coal Company, British Columbia, in May 1902, when 127 lives were lost. He considers such explosions are often closely connected with seismic disturbances, and that the connection is one which should be closely studied and observed.

H. Cunynghame* and W. N. Atkinson have prepared, as a Parliamentary paper, a report on the disaster which occurred at Courrières colliery, Pas de Calais, on March 10, 1906. The report is criticised by James Ashworth.†

The disaster at the Courrières collieries is described and discussed by F. Schreyer,‡ who attributes it to one of three causes—a fire-damp explosion pure and simple, which he thinks improbable; a coal-dust explosion, started by the ignition of a small quantity of gas; or the explosion of fire-damp collected in the old workings from other unworked seams above or below that in which there was a fire.

H. Schmerber § discusses methods of preventing accidents in mines. He classes the chief causes of casualties into eight groups, namely, (1) Fire-damp explosions, (2) dust explosions, (3) fires, (4) flooding, (5) evolution of carbon dioxide, (6) faults, (7) the explosion of subterranean magazines, and (8) the various accidents which occur in connection with mining machinery, such as the fall of cages, &c. He then deals with recent examples of each of these causes, and specially with the catastrophe at Courrières.

As a result of the Courrières disaster the Austrian Government has instructed the various mining district authorities to consider the existing colliery conditions, and to enforce such precautions as may prevent the possibility of any similar accident in Austria. Attention is to be in particular directed to life-saving appliances and their control.‖

B. H. Thwaite ¶ discusses the prevention of explosions in coal-mines, with special reference to palliating the associated toxic fatalities, which are responsible for more deaths than the actual explosions themselves. He outlines the causes which lead to the generation and escape of explosive mine gases.

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* *Cd.* 3171. Price 1s. 7d.

† *Engineer*, vol. cii. p. 470.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 171–175, and 331–334, with one illustration.

§ *Génie Civil*, vol. xlviii. pp. 361–364.

‖ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 261–262.

¶ *Transactions of the Institution of Mining Engineers*, vol. xxx. pp. 388–403.

T. Cook [*] describes an ignition of fire-damp resulting from the firing of a charge of bobbinite in the Lower Drowsell seam of the New Broughton colliery.

H. Steinhoff [†] describes three fatal accidents caused by defective ventilation at the König colliery in Upper Silesia.

The Lighting of Collieries.—Various forms of safety-lamps and modes of lighting collieries are described by E. Harzé.[‡]

An Austrian form of electric safety-lamp is described and illustrated.[§] This weighs 4·85 lbs., is of three-candle power, and gives a light during ten hours. An escape of acid is impossible, and the lamp may therefore be carried upside down. Other advantages are also claimed.

O. Ledouble [||] gives an account of the experience with benzene safety-lamps at the Bayemont colliery. Compared with oil lamps the illumination is better, and there is a slight economy in cost of upkeep.

In a paper read before the Austrian Association of Engineers and Architects, E. Goedicke [¶] discusses the present position of acetylene lighting for colliery workings, making special reference to his types of this lamp designed by Friemann and Wolf of Zwickau, Saxony. These are illustrated and described in detail. For acetylene lamps it was claimed by Sauer in the discussion that they give far better light than oil lamps, are cleaner, and half as cheap again as regards working costs. This referred to the open form of lamp for workings free from gas, and was based on the working results for the year 1904 of the Mitterberg mines near Bischofshofen.

Recent experiments with acetylene safety-lamps are described by M. Mengelberg.[**]

Didier,[††] describing the acetylene lamps used in mines, expresses the opinion that the method of supplying water in the lamps is susceptible of improvement, but that the lamps available give a better light than the ordinary safety-lamps.

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[*] Paper read before the National Association of Colliery Managers, June 30, 1906; *Iron and Coal Trades Review*, vol. lxxiii. p. 116.

[†] *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. liv. pp. 298–299, with plate.

[‡] *Annales des Mines de Belgique*, vol. xi. pp. 57–99.

[§] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 441–442, with one illustration.

[||] *Annales des Mines de Belgique*, vol. xi. pp. 267–269.

[¶] *Zeitschrift des Oesterreichischen Ingenieur- und Architekten-Vereines*, vol. lviii. p. 585; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv., *Beilage*, pp. 50–53, with eight illustrations.

[**] *Die Verhandlungen und Untersuchungen der preussischen Stein- und Kohlenfall-Commission*, Part VII. pp. 642–645.

[††] *Revue Noire*, 1906, pp. 357–359.

Underground Fires.—J. Jeffries * deals with the causes which led to the occurrence of an underground fire at the Greta colliery, New South Wales. The coal-seams of the Greta measures are worked with naked lights, and for the first sixteen years of its history little trouble was experienced from spontaneous fires. From 1897 onwards occasional gob fires occurred, and he attributes them to the oxidation of the iron pyrites with which the coal is in parts somewhat contaminated.

L. W. Llewelyn † describes the extinction of the fire in the 6-foot seam of the Cambrian collieries. The fire was the outcome of an explosion of March 10, 1905.

J. Mayer ‡ describes a method for extinguishing fires in gassy collieries where there is an inadequate ventilation. An explosion of fire-damp is, he observes, often followed by a mine fire, and this again by a series of minor explosions. As a rule these only occur in very gassy collieries; but they then do very great damage, as the author shows in connection with an Austrian explosion. Thirty-nine days after the first explosion another and very violent one resulted. It is with conditions such as these that the author deals.

The spontaneous ignition of coal stored in bulk is discussed by V. B. Lewes. § A careful study of the phenomena occurring during the heating of a mass of coal leads to the conviction that the pyrites present can only play a very subsidiary part, and that it is in reality the absorption of oxygen by the freshly won coal, and the activity of the condensed gas in contact with the hydrocarbons of the coal, that are the active factors in causing the ignition. The mere absorption of the oxygen, however, is insufficient to bring about serious consequences, unless there is an initial rise in temperature to start the action.

Heidepriem ‖ observes that the old Liebig hypothesis, that the spontaneous combustion of coal was due to the oxidation of pyrites, cannot well be maintained from thermo-chemical reasons. Spontaneous combustion appears with greater probability to be caused by the oxidation of carbon. When burning takes place, the only rational means has been found to be to turn over and sprinkle the coal with water. Good results have been obtained on ships with carbonic acid.

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* *Transactions of the Institution of Mining Engineers*, vol. xxix. pp. 518–546.

† *Proceedings of the South Wales Institute of Engineers*, vol. xxiv. pp. 542–559.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 345–347, with one sheet of illustrations.

§ *Journal of the Society of Arts*, vol. liv. pp. 927, 941, 957, 973; *Journal of Gas Lighting*, vol. xciv. pp. 33–34.

‖ *Zeitschrift des Bayerischen Dampfkessel- Revisions-Vereins*, 1906, Nos. 7–8.

E. Simonsen * considers the causes of the spontaneous combustion of coal, and gives measures of safety. The causes are: excessive height of the coal heap, tipping fresh coal on to the remaining damp coal in the store, partial wetting through rain, high percentage of pyrites. The measures of safety recommended are: internal ventilation, reduced height of coal heap, placing steel bottles containing compressed carbonic acid and closed by metal fusible at 70° C.

Life-saving Appliances.—The Fleuss-Davis self-contained safety-breathing apparatus for use in mines is described and illustrated.† It depends on the regeneration of the exhaled breath in a special reservoir carried by the wearer, by passing it through caustic soda and simultaneously renewing the oxygen supply. The appliance, furnished with an air supply sufficient for four hours, weighs 19½ lbs.

R. Cremer ‡ describes the pneumatogen invented by Bamberger and Böck. In this apparatus the use of compressed oxygen is dispensed with, the oxygen being automatically generated from alkaline peroxides. The complete apparatus weighs only 7 lbs., as compared with 39½ lbs. for the Meyer apparatus, and can supply oxygenated air for 120 to 140 minutes, during fairly violent exercise, and four or five hours if the user is quiescent. A smaller apparatus, weighing only 2 lbs., is also described.

An account has been published § of the Exhibition of Hygiene in Vienna. An interesting section was that including rescue appliances for mining use.

J. Mauerhofer || discusses the life-saving arrangements in use at the Count Wilczek collieries in Polish-Ostrau.

F. Pospíšil ¶ describes the underground safety stations of the

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* *Teknisk Ugeblad*, vol. liii. p. 75.

† *Engineering*, vol. lxxxi. pp. 480–481.

‡ *Iron and Coal Trades Review*, vol. lxxiii. pp. 11–12.

§ *Montan Zeitung*, vol. xiii. pp. 168–169.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 267–273, with eleven illustrations.

¶ *Ibid.*, pp. 293–297, with two illustrations.

collieries belonging to the Kaiser Ferdinand's Northern Railway in Moravian-Ostrau. The rules relating to these are also given.

The Suess safety breather is described by Popper.[*] In this apparatus liquid air is employed. No valves are needed, and the apparatus is very simple.

J. Andreics[†] describes the adoption of the Shamrock type of rescue apparatus at the Zsily collieries, Hungary.

M. Bamberger[‡] and F. Böck discuss the chemistry and mechanics of rescue appliances for collieries.

H. Meyer[§] deals with the training of mining rescue corps.

H. Grahn[‖] gives particulars of the practical exercises in colliery rescue work arranged for the students of the Bochum School of Mines.

F. Lebreton[¶] describes the use of the Vauginot, and of the Guglielminetti-Dräger apparatus, for the exploration of places filled with irrespirable gases.

J. Philipp[**] describes a stretcher for use in mines. This is an Austrian device.

R. H. Dundas[††] draws attention to the use of bore-holes in mines as means of communication should disaster occur, and a method of passing provisions and supplies to entombed miners.

Colliery Surveying.—H. Briggs[‡‡] discusses the methods of mine surveying in England as compared with those in the United States and Germany.

Particulars of the mine surveys in the driving of the Ladysmith drift in the undersea extensions at the Whitehaven collieries are given by J. Shanks.[§§]

Sanitation at Collieries.—The design and construction of workmen's dwellings are dealt with by K. Henrici.[‖‖]

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[*] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. p. 552.

[†] *Banyaszati es Kohaszati Lapok*, vol. xxxix. p. 491.

[‡] *Glückauf*, vol. xlii. pp. 584–590.

[§] *Ibid.*, pp. 639–642.

[‖] *Ibid.*, pp. 665–679.

[¶] *Annales des Mines*, vol. vii. pp. 655–678.

[**] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 399 401, with three illustrations.

[††] *Iron and Coal Trades Review*, vol. lxxii. pp. 1320–1321

[‡‡] *Colliery Guardian*, vol. xcii. pp. 18–19.

[§§] *Transactions of the Institution of Mining Engineers*, vol. xxxi. pp. 166-174.

[‖‖] *Zeitschrift des Vereines deutscher Ingenieure*, vol. l. pp. 952–956.

Riemann[*] and E. Pietsch direct attention to the value of salt-water in preventing the development of ankylostoma in mines.

A. Manouvriez[†] describes the methods to be adopted for rendering coal-mines uninhabitable by ankylostoma. He cites the experiments of Perroncito, who in 1880 showed that concentrated solutions of common salt destroyed the newly-born larvæ of ankylostomes; and in 1904 H. Bruns showed that a 4 per cent. solution destroyed the eggs and 3 per cent. the larvae of nematoda. Certain cavities and workings in the Anzin collieries have been found immune to ankylostoma owing to infiltration of saline liquors from adjacent deposits. These liquors, which would appear to have been derived from ancient sea-waters trapped in geological ages, contained 14·675 per cent. of sodium chloride.

The occurrence of ankylostomiasis in the Blanzy district of France is discussed by de Morgues.[‡]

Z. Inouje[§] points out that whereas ankylostomiasis is specifically a miner's disease in European countries, in Japan it more frequently attacks the agricultural population. The chief remedies employed are an ethereal extract of male fern, and thymol.

History of Coal-Mining.—In an address to the Historical Society at Wellsboro, Pennsylvania, A. Hardt[‖] traces the history of mining in Tioga county, Pennsylvania.

IX.—*COAL WASHING AND SCREENING.*

Coal-Screening.—E. A. Hersam[¶] deals with the size of screens, and points out the necessity of giving the actual size of the holes employed. He gives exhaustive tables of the sizes in use in America in relation to the wire employed, and in comparison with standards adopted elsewhere.

J. Diviš[**] discusses Henry's experiments on coal separation and his system of hydraulic propulsion for plant of this type.

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[*] *Glückauf*, vol. xlii. pp. 683–685.

[†] *Revue Universelle des Mines*, vol. xii. pp. 171–191.

[‡] *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1906, pp. 50-51.

[§] *Zeitschrift für Gewerbliche-Hygiene*, 1905; *Revue Universelle des Mines*, vol. xii. p. 111.

[‖] *Mines and Minerals*, vol. xxvi. pp. 484–486.

[¶] *Bi-Monthly Bulletin of the American Institute of Mining Engineers*, 1906, pp. 423–445.

[**] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 305–309 and 321–325, with twelve illustrations; *Revue Universelle des Mines*, vol. x. pp. 274–305.

M. F. Peltier* describes the surface plant of the Springfield coal-mine of the Peabody Coal Company, and the method of screening employed at that colliery, which is one of the most modern plants in Illinois. The plant is designed to handle 2500 tons of coal per eight-hour shift. The plant described includes the pithead gear, cages, tipple, and screens.

Heapsteads and screening plant are fully dealt with in the articles on the mechanical engineering of collieries by T. Campbell Futers.†

Coal-Washing.—Progress in coal-washing in 1905 is reviewed by R. H. Richards.‡

The improvements in coal-washing during the last twenty-five years in the Ruhr district are described by O. Simmersbach.§ The older systems of F. M. Simmersbach and Schüchtermann and Cremer are specially dealt with. The latest Baum washer treats coal, without first classifying from 0 to 3 inches, according to the fundamental rule of "first classify and then wash." The plant principally used consists of jiggers driven by air, classifying trommels with screens placed one over the other, and a wet separating belt. The water flowing away from this is cleared and returned to the washer, the slimes being led to the separating basins.

Coal-Handling.—The mechanical appliances used at the Alexandra Docks, Newport, are described by John Macaulay,‖ those at the Bute Docks, Cardiff, by H. S. C. Ree,¶ and those at Penarth Docks by T. Hurry Riches** and T. E. Heywood.

The new coal-bunker and band conveyor of the Bargoed and New Tredegar collieries are figured and described.†† The bunker has a capacity of 800 tons, and the conveyor has a capacity of 50 to 60 tons per hour, and is 18 inches wide.

The electric telpher for conveying coal, recently installed at the Bevan works of the Associated Portland Cement Manufacturers (1900), Ltd., is described and illustrated.‡‡ The capacity of the plant is 400 tons per day.

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* *Engineering News*, vol. lv. pp. 261–262.

† *Colliery Guardian*, vol. xcii. pp. 935, 980.

‡ *Mineral Industry*, New York, vol. xiv. pp. 639–645.

§ *Berg- und Hüttenmännische Rundschau*, 1906, No. 13.

‖ *Proceedings of the Institution of Mechanical Engineers*, July 30, 1906.

¶ *Ibid.*

** *Ibid.*

†† *Engineering*, vol. lxxxi. pp. 117–118.

‡‡ *Ibid.*, vol. lxxxii. pp. 44–46.

J. Schnell* gives an account of the mechanical loading appliances for coal and ore at the wharf of the Gutehoffnungshütte at Walsum.

The new Hulett coal-handling conveyor bridges at Boston Coal Dock, Duluth, Minnesota, are described and illustrated.† The buckets can be hoisted at a speed of 250 feet per minute, and cross traversed at 1000 feet per minute, each bucket holding 2 tons of coal.

An illustrated description is given by F. Perkins‡ of large coal-handling installations at shipping ports. Among the plants described are those of the Sikuko Railway Company in Japan; the appliance at the Princes Dock, Glasgow; and the Hulett machines at the United States Steel Corporation Docks at Conneaut.

Storage of Coal.—W. H. Beehler§ advocates storing coal under salt-water in order to obviate danger and losses caused by fire.

Storage of coal, when exposed to atmospheric influences, leads to considerable deterioration, the loss being the greater the larger is the surface of the exposed coal relatively to its bulk. This was at first attributed solely to the influence of atmospheric moisture and rain, but subsequently the action of oxygen was also recognised. C. W. Meyer‖ considers, however, that it is not so much the water itself that plays an important part in this deterioration of the fuel as the oxygen it holds dissolved in the form of ozone. Air itself contains at the most but a thousandth part of this constituent, but it may reach from 36 to 54 times this quantity in water. The town of Königsberg has new gasworks which until recently was obliged to store its coal in the open. At the old gaswork there was a storage-chamber filled with coal and carefully closed. Comparison between this coal and that stored in the open: the latter coal yielded 15 per cent. less gas, and only about half the quantity of ammonia which the coal stored in the closed storage-chamber yielded.

Briquette Manufacture.—K. A. Muellenhoff¶ describes the briquetting of brown-coal in Saxony, Brandenburg, and Silesia, where enormous deposits exist. The methods differ widely from those employed in briquetting bituminous coal. The brown-coal is mined mostly in open pits. It is crushed to small pieces, and delivered on shaking screens, the coal passing ⅜-inch meshes. The coal during this process retains its hygroscopic water, and is subsequently dried at about 230° F., and taken by a helical conveyor to a rotary sieve. The hoppers into which it is next received are cooled, and the coal is then pressed into briquettes under a pressure of 17,000 to 22,000 pounds per square inch. The sudden rise in temperature due to this enormous pressure softens the bitumen of the coal, and this hardens at once in contact with the water-cooled sides of the moulds. Most of the briquetting plants are now operated by power developed from electric generating stations, utilising exhaust steam. The effective heating value of the product is 9000 British thermal units, as against 3600 British thermal units in the original coal.

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* *Glückauf*, vol. xlii. pp. 781–783.

† *Iron Age*, vol. lxxvii. p. 1669.

‡ *Génie Civil*, vol. xlviii. pp. 169–172, with five illustrations.

§ *Proceedings of the United States Naval Institute*, June 1906.

‖ *Journal für Gasbeleuchtung und Wasserversorgung*, May 19, 1906.

¶ *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xxii. pp. 178–195.

A description has appeared of the briquette factory at the Alexander brown-coal mine at Herrlich, Bohemia.* It is designed to turn out 1000 tons of briquettes in 24 hours.

G. J. Mashek † describes the Zwoyer process of briquetting fuels, and the experimental plant installed by the New Jersey Briquetting Company, in Brooklyn. Coal-tar pitch, or asphalt, is used for binding, and the briquettes are made from anthracite dust, to which a small percentage of soft coal has been added, which makes the briquettes harder. Illustrations of the plant are given.

Some notes on fuel briquetting in America is given by C. M. Barber.‡

E. J. Constam § and R. Rougeot deal with chemical methods for the valuation of briquettes.

E. Leber || gives details of the Emden Dock plant, and of the works erected there. These include a large briquette works to make from 150,000 to 200,000 tons of briquettes a year, machinery plants, &c. Details are also given as to the traffic through the port, and illustrations are shown of travelling cranes and other appliances now in use.

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* *Montan Zeitung*, vol. xiii. p. 284.

† *Iron Age*, vol. lxxvii. pp. 1330–1332.

‡ *Mining World*, vol. xxiv. pp. 329–330.

§ *Glückauf*, vol. xlii. pp. 481–492.

|| *Stahl und Eisen*, vol. xxvi. pp. 513–522, with ten illustrations and one map.

PRODUCTION OF PIG IRON.

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I.—*BLAST-FURNACE PRACTICE.*

Theory of the Blast-Furnace.—R. Schenck* and W. Heller have investigated the pressures and temperatures affecting the mutual actions of iron and its oxides with carbon and its oxides. They find that when carbon monoxide is heated with metallic iron, the pressure observed after equilibrium is attained is extremely small, and it appears that practically all the gas is removed. This results from the oxidation of the iron and the deposition of carbon in the solid form. As pure carbon monoxide cannot oxidise iron, it is assumed that the iron reacts in two distinct ways: (*a*) Catalytically, decomposing the monoxide into carbon and the dioxide; (*b*) as a reducing agent on the dioxide producing ferrous oxide and carbon monoxide. These two reactions proceed until equilibrium is established between iron, ferrous oxide, carbon, and the two oxides of carbon. Working under normal conditions—that is, under atmospheric pressure—there can be no reduction if no inert gas be present, below about 765° C., for only at that temperature is the equilibrium pressure equal to the total pressure of the reacting gases; and to work at a lower temperature it is necessary to reduce that total pressure, either by working in a partial vacuum or by diluting with an inert gas. In the blast-furnace, where air is used to produce carbonic oxide, the total pressure of the carbon oxides cannot exceed 250 millimetres, and hence reduction may occur at all temperatures above about 695° C. In a blast-furnace worked with wood charcoal it follows that (for any given temperature) the composition of the gaseous mixture will be richer in carbon monoxide than the gaseous mixture of a furnace worked with coke, which is allied to graphite.

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* *Engineering*, vol. lxxxi. p. 471.

The Dry-Air Blast.—C. A. Meissner* summarises recent criticisms on the Gayley dry-air blast process. Increased blast temperature alone cannot account for a decrease of 20 per cent. in coke consumption, and an increase of 20 per cent. in the production of pig iron. There was no significant increase in blast temperature at the Isabella furnaces while they used dry-blast; and the records showing a low fuel consumption are not characterised by a blast temperature sufficiently higher than that of the Isabella furnaces to account for their economy in fuel. The economy is doubtless due to innumerable local conditions, which every scientific furnace-manager takes into account. The theoretically calculated effect of higher blast temperature upon fuel economy, though possibly realised in isolated cases, is not confirmed in general practice. which indicates a considerably lower net result. Modern blast-furnaces, equipped with stoves for producing high temperatures of blast, have undoubtedly achieved much, but not enough to equal the gains secured by drying the blast. The proposition that an increase of 300° F. in blast temperature would effect a decrease of 400 lbs. in coke consumption per ton of pig iron produced is not confirmed by available records of practice. Of furnaces using natural-air blast, it is usually the new ones that show high production with low coke consumption. As the period of operation increases, the tendency to a reversal of these results becomes more evident. To this general rule there are a few exceptions, largely due to local conditions, not duplicated at other plants. The advantageous results obtained from the dry-blast are not sensibly affected by changes of season. With due allowance for local conditions, it may be safely inferred that, at furnaces averaging more than 2100 lbs. of coke per ton of product, from 10 to 20 per cent. of gain in product and of saving in fuel can be effected by the use of dry-blast. At furnaces already using less than this proportion of coke, the gain may be somewhat smaller. Apart from all other theoretical gains realised by the desiccation of the blast, his study of the records of practice impresses upon him the predominant importance of the uniform and regular running of the furnace thereby secured. The desirability of removing moisture from the blast had been frequently suggested by technical authors, but the theoretical advantages to be thus realised did not seem to be commensurate with the expenditure involved. It remained for J. Gayley to demonstrate a gain, not included in theoretical arguments, yet perhaps greater than any other therein considered; namely, that of uniform and perfectly controllable furnace operation, and the consequent diminution of the amount of superfluous fuel hitherto carried as a "margin of safety," to meet the unforeseen contingencies of the "behaviour" of the blast-furnace. In the discussion which followed, H. M. Howe considered regularity, in and by itself, did not in the least explain why the fuel economy was so great, the economy of the dry-blast process, like that of the hot-blast process, being due essentially to its widening the margin between the temperature developed by combustion and the "critical" temperature, *i.e.*, the temperature at and above which certain essential work of the blast-furnace process must be done. As J. E. Johnson, jun.,* points out, for the work which has to be done above the critical temperature, the only heat available is that which the gases can give out in cooling to this temperature from their combustion temperature, *i.e.*, the temperature to which the combustion in the hearth of the furnace raises them. The economy of the dry-blast process, like that of the hot-blast process, is essentially due to the fact that each of these processes raises the temperature which the combustion in the hearth gives to the gaseous products of that combustion, and thus widens the margin between the combustion temperature and the critical temperature; and it is the width of this margin that, in a rough way, measures the degree to which the heat generated can be utilised. If the critical temperature is 1200° C. and the combustion temperature 1300°, there is a margin of only 100°; by raising the combustion temperature by 100°, or by only 8·5 per cent., the margin is doubled, and the utilisation of the heat is increased correspondingly. The reason the importance of the margin had generally been overlooked is that, in most heating processes, the margin is naturally so wide that slight current variations are unimportant. The natural narrowness of the margin in blast-furnace processes gives the hot-blast and the dried-blast their very great value, and will some day give a still greater value to processes for lessening the nitrogen in the blast. J. W. Richards pointed out that the uniform conditions obtained by drying the blast would produce no economies if they were not uniformly favourable. If they were uniformly the worst the blast-furnace manager would have uniformity, but not economy. With blast not dried, the non-uniform conditions which cause unfavourable irregularities are the varying temperature and moisture-content of the outside air. With cold, dry air the furnace does its best; with warm, moist air it does its worst; sudden changes cannot be altogether foreseen; and the manager must always be prepared for them by using a large fuel-ratio in the charge. The dry-blast provides the uniformly favourable condition, and therefore gives the basis for the economies realised. With blast of uniformly low temperature coming to the blowing cyclinders, more oxygen is pumped into the furnace per day, thus increasing the rate of driving, other conditions remaining fixed; while the absence of moisture in the dried blast results in a higher temperature in the region of the tuyeres, increases the reducing power and smelting down capacity, and incidentally induces several other favourable conditions. Thus the dried blast produces regularity of the uniformly favourable type, as distinguished from an unfavourable uniformity.

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* *Bi-Monthly Bulletin of the American Institute of Mining Engineers*, 1906, pp. 385–421.

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* *Transactions of the American Institute of Mining Engineers*, vol. xxxvi. p. 454.

F. Firmstone considers that most of the fuel saved by drying the air is due to indirect advantages. Although the dry-air furnace was shown to receive 1535 less calories from the hot-blast than the moist-blast, a decidedly larger proportion of the total heat comes from this source than in the moist-air furnace (10·26 per cent. in the moist air, 11·21 in the dry air). This is of the greater importance, because heat in the blast corresponds to carbon in the coke burned to CO_2, and not in large part to CO, as does the heat produced in the furnace itself.

R. W. Raymond said that irregularity of furnace-work meant at least ten times as much loss of money as formerly. The argument of Richards suggests an analogy with constructive engineering, namely, that of placing material just where it is needed, instead of wasting it elsewhere. Such an economical distribution of material in a structure is practicable in proportion as the strength of each part, and the uniform amount or limits of variation of the strain upon it, are known. The necessity of a vaguely determined "factor of safety" is a hindrance. In a similar way, the measurable elimination of such a factor in the heat-supply of the blast-furnace permits the heat to be supplied at the point where it will be theoretically most effective, instead of at points where it may be accidentally needed, but is normally less useful, and sometimes, in certain respects, harmful. Within certain limits, uniform conditions are more economical in practice than fluctuating conditions. The latter prevent a furnace from working up to any formula of efficiency that may be framed for it, no matter with what liberal allowances for contingencies. Regularity does more than secure a regular income. It protects the furnace against premature destruction. Since the cost of re-lining, &c., for a new campaign must be repaid with interest by the product of that campaign, the length of the campaign is an important element of economy.

J. Gayley, in reply, said, whether or not the increased uniformity obtained by the use of dry air explained the economies thereby effected, it made possible, nevertheless, the various theories brought forward to account for those economies. The drying of the air not only removes an unfavourable and varying element from the blast, but by keeping the content of moisture in the dry air practically uniform, through refrigeration to a uniform temperature, permits the delivery into the furnace of a practically constant weight of air, and therefore of oxygen—a result which cannot be obtained through an increase in blast-temperature. The elimination of moisture removes a heat-extracting element at the tuyeres, and, together with the uniform weight of oxygen constantly supplied, intensifies the combustion, and localises and lowers the fusion-zone. With natural air the fusion-zone is constantly fluctuating; when the zone is lowered, incipient scaffolds form on the area through which it is lowered; and when the zone is again raised, these scaffolds are melted loose, and, descending into the hearth, absorb heat. For this purpose alone, a margin of safety in fuel must be carried in the burden. He suggested certain further economies, both practical and theoretical, in the application of dry-air blast. The original plant at Isabella was designed solely to determine the value of dry-air blast, with a minimum of expenditure. Only one refrigerating-chamber was provided. It would have been better to divide this chamber by partitions, with an outlet from each division to the blast-main, that could be closed during the thawing-off period. Every day, one-third of the coils are thawed off; and, with the present construction, the quantity of moisture in the air supplied to the blowing-engines during this process is increased 50 per cent. From theoretical calculations, it appeared that an economy in construction could be effected by conducting the operation in two stages; that is, by passing the air first over coils cooled to 30° F., and condensing a considerable portion of the moisture as water, after which, by passing it over a series of coils at a much lower temperature, it could be reduced to the desired temperature, while the moisture would be deposited as frost. Since the water from the first cooling would flow away, thus leaving a smaller amount of frost to be removed by thawing, this arrangement seemed advantageous. But when the data were supplied to manufacturers of refrigerating machinery, the estimates they furnished showed that there would be actually no economy in construction, and the saving in operation was indicated to be very small. The two-stage system appears to be more difficult of adjustment to varying conditions, and to involve more complications in operations —which are not desirable, since economy of power would depend on the proper adjustment of the two stages. The experience of eighteen months with dry-air blast has demonstrated several facts: (1) The charges settle more quickly and uniformly after casting than in a furnace blown with natural air; (2) the loss in flue-dust is about 2 per cent. less; (3) the furnace works with greater regularity, and off-grades of iron, which are usually sold at a considerable reduction in price, are seldom made, for dry-air blast maintains the regularity of the grade of output, which, in a merchant-furnace, is a considerable advantage. In the product of a furnace blown with natural air, when the silicon is lowered, the sulphur often is increased to such an extent that the pig mnst either be re-melted, or sold at a material reduction in price. With dry-air blast, it has been found that there is rarely an appreciable increase in sulphur corresponding to a material reduction in silicon. The ability to produce pig iron according to standard specifications, with increased uniformity of grade and composition, makes this process specially valuable to merchant-furnaces, in the operations of which a considerable profit is habitually sacrificed in the marketing of "off" grades of pig iron.

J. W. Richards* deals with the mathematical considerations involved in the production, heating, and drying of the air-blast at furnaces, and gives copious examples and formulæ for ascertaining the amount of fuel, volume of air, and pressure of blast necessary for satisfactory practical working.

The Steinbart dry-air blast system is discussed.† In this system the air is passed from the blowing-engine at a pressure of about 15 pounds per square inch, through a species of surface-condenser, in which ordinary river water circulates. An experimental apparatus was fitted up in October last year at Pittsburg, and the results obtained were both cheap and satisfactory.

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* *Electrochemical and Metallurgical Industry*, vol. iv. pp. 383–388.

† *Engineer*, vol. ci. pp. 401–402.

F. A. Willcox,* commenting on the Steinbart process, points out that although its adoption may reduce the first cost on refrigerating plant, yet it it questionable whether it can effect the economies produced by the Gayley process.

Various descriptions of refrigerating machinery, depending upon ammonia absorption, are described,† including a large Cracknell machine made by Ransomes & Rapier.

Velocity of Hot-Blast.—R. Vambera ‡ and F. Schraml have published an exhaustive memoir on the direct measurement of the velocity of hot-gas currents with the aid of Pitot tubes. The method is of special value in ironworks, inasmuch as it is applicable for gases whether hot or cold, and where pure or contaminated with flue-dust and acid vapours. The method has, however, hitherto been rarely used in works. The memoir deals with the following subjects: Methods for the direct measurement of the velocity of gas currents (1) by means of floating bodies, (2) by means of anemometers, (3) by means of the Pitot tube; measurements of velocities in gas-flues of various kinds, (1) in boilers, (2) in blast-furnaces, (3) in lead-works, and (4) at the Königshof ironworks. A bibliography of the subject is appended, and the memoir is accompanied by two plates and twenty-five illustrations in the text.

Nitrogen in the Blast-Furnace.—In reviewing recent progress in the metallurgy of iron and steel, Bradley Stoughton § points out that it has not yet been ascertained whether or not blast-furnaces and Bessemer converters will ever be blown with oxygen less diluted with nitrogen than the atmospheric air. The only obstacle is the cost of producing the oxygen. Some means of employing the residual nitrogen would materially cheapen the use of oxygen separated out of the air, but nitrogen is so inert chemically that although its compounds are valuable, the cost of combining it has been too great. Important advances have recently been made in this regard. The two methods of fixation of atmospheric nitrogen which are commercially most promising are (1) producing combustion by means of an electric arc, and (2) producing a reaction between calcium carbide and atmospheric nitrogen, which forms a valuable fertiliser. Further information on the subject is given by P. A. Guye,* by R. K. Duncan,† by F. Mollwo Perkin,‡ and by W. H. Hobbs.§

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* *Engineer*, vol. ci. p. 471.

† *Engineering*, vol. lxxxi. p. 341.

‡ *Berg- und Hüttenmännisches Jahrbuch der k. k. Montanistischen Hochschulen*, vol. liv. pp. 1–98.

§ *Mineral Industry*, New York, vol. xiv. pp. 349–350.

W. Muthmann ‖ reviews the methods proposed and gives a bibliography of the subject. The subject is also dealt with by H. Leicester Greville ¶ and by F. Foerster.**

E. Lemaire †† describes the Bradley and Lovejoy electric process and that of Birkeland and Eyde. Both these processes have passed beyond the experimental stage and are in actual operation, the first-named at Niagara Falls and the second at Notodden in Norway. The results produced by these methods are compared with those resulting from the Kowalski Moscicki process, which is in operation at Freiburg, Switzerland. The energy required to effect the manufacture of nitrogen from the air by means of electricity is calculated, and the application of the electric arc for the purpose is described. Notwithstanding the numerous experiments which have been made, the results differed greatly from those which, theoretically, should be attained. At the same time so much progress has been made of recent years that it may be anticipated that before long the industry will assume profitable dimensions.

Blast-Furnace Calculations.—J. W. Richards ‡‡ deals with the balance-sheet of the blast-furnace, taking as the basis of his calculations the working of a furnace at Herräng using ore briquettes, with charcoal as fuel and limestone as a flux.

Improvements in Blast-Furnace Practice.—L. Bréda §§ describes the metallurgical section of the Liége Exhibition, with special reference to the exhibits showing the progress of blast-furnace practice. The Actien-Gesellschaft Schalker Gruben und Hütten-Verein, of Gelsenkirchen, showed a model of a new form of blast-furnace shell formed of cast-iron rings fastened together with bolts and lined with refractory bricks. The shell is water-cooled. Two large furnaces on this system have been built at Bruckhausen on the Rhine and at Dortmund respectively, of 500 tons capacity, daily, besides smaller ones elsewhere. The Buderus furnace top is also described. In this appliance means are devised for drawing of the central gases, as well as those at the sides of the furnace, by providing a double top, by means of which losses of gas are obviated and the charge is more evenly distributed in the furnace.

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* *Electrochemical and Metallurgical Industry*, vol. iv. pp. 136–139.

† *Harper's Monthly Magazine*, April 1906.

‡ *Nature*, vol. lxxiv. pp. 444–446.

§ *Mining World*, vol. xxiv. p. 666.

‖ *Zeitschrift des Vereines deutscher Ingenieure*, vol. l. pp. 1169–1176.

¶ *Journal of Gas Lighting*, vol. xcvi., July 24, Aug. 7.

** *Zeitschrift für Elektrochemie*, vol. xii. pp. 551–558.

†† *Génie Civil*, vol. xlviii. pp. 308–312, and 328–330.

‡‡ *Electrochemical and Metallurgical Industry*, vol. iv. pp. 129–132.

§§ *Revue Universelle des Mines*, vol. xiii. pp. 31–37.

J. A. Leffler * gives the results of experiments with blast-furnaces with wide and with narrow boshes at Långshyttan.

Reference is made † to the use of acid bottoms in blast-furnaces. Up to ten years ago they were not in general use, and the experience gained with them since then is now outlined; and analyses are given to show that they do not take up much iron even after long use. The following is an analysis of the material of a bottom of this kind:—

	Per Cent.
Ferric oxide	1·70
Alumina	5·20
Silica	89·80
Lime	1·40
Magnesia	0·20
Loss on ignition	1·60

Manganese Ore in the Blast-Furnace.—E. Hollmann ‡ deals with the smelting of iron ores rich in manganese. The reduction of manganese, which amounts to only from one to two-thirds of the total contents, depends as much on the conditions of working, such as the temperature of the blast, section of the furnace and pressure of the blast, as on the physical and chemical properties of the ore, and therefore also depends on the percentage of manganese. Reduction can be increased by slower smelting or by increasing the charge of coke. The best method can only be discovered by exact calculation. The higher the percentage of manganese in the pig iron, the higher the total amount of manganese in the slag and also its percentage. The larger quantities of slag absorb in an increased measure the reduced manganese, and the conversion of manganese is again influenced by the composition of the low percentage ore which is added. The amount of manganese used for the iron in the manganese ore and for the resulting slag, and also the amount remaining for smelting the ore added and its slag must be determined. An exact calculation is given, taking into consideration all influences, and examples are given for the different sorts of iron. It follows from the calculations that the value of the manganese in manganese ores depends not only on the percentage present, but also to a large measure on the iron ores which are smelted with them, and to a less degree on other factors, such as the addition of coke and lime, moisture, and other conditions.

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* *Bihang till Jernkontorets Annaler*, 1906, pp. 333–339.

† *Stahl und Eisen*, vol. xxvi. pp. 1191–1193, with three illustrations.

‡ *Berg- und Hüttenmännische Rundschau*, vol. ii. pp. 135, 153.

Charging Arrangements.—Blast-furnace hoists are described by G. von Hanffstengel.*

Some recent blast-furnace charging arrangements are described by B. Müller.†

A description of the Dougherty blast-furnace charging machine is given.‡ It consists of a series of hoppers and bells so disposed that the stock may be deposited in the furnace at will in any one of three different zones, namely, centrally in the furnace, at the sides, or in the intermediate space.

Charcoal Blast-Furnaces.—The manufacture of charcoal pig iron in America is described by O. Falkman.§ Details of the cost of production in Michigan and Alabama are given. The cost of production is stated to be 47s. in Michigan and 43s. 6d. in Alabama.

Purifying Boiler Feed-Water.—An illustrated description has appeared || of the new Criton water softening installation recently installed at the steel works of Howell & Company, Limited, Wincobank, Sheffield. The plant is capable of dealing with 5000 gallons of water per hour, and derives its supply from a tributary of the Don.

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* *Dinglers Polytechnisches Journal*, 1906, pp. 609–611.

† *Giesserei Zeitung*, vol. iii. p. 197.

‡ *Iron Age*, vol. lxxvii. p. 1679.

§ *Bihang till Jernkontorets Annaler*, 1906, pp. 215-218; *Teknisk Tidskrift, Allmänna Afdelningen*, vol. xxxvi. p. 103.

|| *Iron and Coal Trades Review*, vol. lxxii. p. 1317.

Hot-Blast Stoves.—A description of the Hartman-Kennedy firebrick stove has appeared.* There is an outside combustion chamber to which gas is admitted underneath its dome at the top, and in which it is burned at the focus of the dome. High heat is maintained in the combustion chamber by providing a separate connection to the hot air main, thus preventing heat abstraction by the passing current of air when the stove is on air. The burned gas passes into the stove proper, which is divided into the first and second regenerative chambers. The first chamber is supported on Gothic arches, 12 inches thick, the heavy brick securing a good body of brick work and preventing damage by heat to the arches. The walls of the first regenerative chamber are built of 9-inch by 9-inch brick with 9-inch openings; the second regenerative chamber is provided with openings 5 inches by 5 inches and 2½-inch walls. The heating surface, per foot of height of regenerator, is 280 square feet. Each square foot of heating surface in the stove requires 7·6 9-inch bricks.

Blowing-Engines.—David E. Roberts † traces the development of blast-furnace blowing-engines. He commences by tracing the development of the piston blower from the primitive goat-skin bellows, and pointed out how the old leather flap-valves of the bellows, strengthened with iron and closing against an iron grid, might be found even to-day in many of the older engines. In 1850 Archibald Slate recognised that, for higher speeds, positively controlled valves were necessary; and after experimenting with considerable success in the use of an ordinary slide-valve, he patented an annular valve surrounding the cylinder. A modification of this form was recently adopted in America by Edward Slick. About 1870 Daniel Adamson brought out the well-known Bessemer blowing-engine with piston valves. The next great step was the introduction of separate inlet and outlet valves. Of these arrangements the author describes the Kennedy-Reynolds gear, the Riedler gear, the Southwark gear, and the Slick gear, and comments on their action. The paper goes on to describe the arrangement of early steam blowing-engines, from the beam-engine type to the steeple type. The gas-driven blowing-engine, the author believed, would eventually hold the field, although at present it was costly and troublesome. The turbo-blower, though no more economical than a high-class reciprocating blower, was cheaper, smaller, and gave an absolutely steady blast. What type of plant should be installed must be determined by local conditions. The use of a turbine-blower in connection with ordinary reciprocating steam-blowers is considered in some respects the ideal means of augmenting an existing blowing-plant, though the turbine has the disadvantage of not being a "positive" blower, and moreover shows a slight falling away in volume of blast and in efficiency when the pressure of air is increased above the normal, as is sometimes necessary.

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* *Iron Trade Review*, September 20, 1906, pp. 27–28.

† Paper read before the Institution of Mechanical Engineers, July 1906. *Engineering*, vol. lxxxii. pp. 440–441; *Iron and Coal Trades Review*, vol. lxxiii. pp. 491–493.

O. Jaschke * gives a method for computing the air losses in blowing blast-furnaces, as a guide to the furnaceman, of the actual amount of air entering the stack. The theoretical volume of air blown being ascertained in the usual way, doubling the cubic capacity of one air cylinder, multiplying by the number of revolutions per minute, and multiplying the product by the number of air cylinders working for one furnace, the air entering the stack is ascertained chemically by finding out the amount of nitrogen leaving the furnace in the waste gases per minute, and deducting this from the amount entering the furnace in the first instance.

An illustrated description is given † of a blowing-engine recently installed at the Lowellville plant of the Ohio Iron and Steel Company, by the William Tod Company of Youngstown, Ohio. The engine is designed to operate at fifty revolutions per minute against a maximum working air-pressure of 25 lbs., when supplied with steam at a pressure of 150 lbs.

H. Bonte ‡ discusses the various applications of large gas-engines, specially for driving blowing-engines.

The use of gas-engines for utilising surplus gas from the blast-furnaces has been adopted by the Carnegie Steel Company, the engines being used for the generation of power needed in the electric driving of steel mill machinery.§ Two of the largest gas blowing-engines are being built for the Edgar Thomson furnaces. These are twin units, with the gas and blowing cylinders placed tandem, and having a fly-wheel between the two parts of each unit. These engines are of the heavy duty double-acting type, and each unit has a capacity of 25,000 cubic feet of free air per minute, operating against a normal

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* *Iron Age*, vol. lxxvii. p. 1692.

† *Ibid.*, vol. lxxvi. pp. 1139–1140, with four illustrations.

‡ *Zeitschrift des Vereines deutscher Ingenieure*, vol. l. pp. 1362–1368

§ *Engineer*, vol. cii. p. 64.

blast pressure of 18 lbs., and running at a speed of 60 to 75 revolutions per minute. For the Bessemer Works the company has ordered a gas-engine which will drive a direct-connected electric generator to increase the present power available at these works. The engine will have a stroke of 54 inches, the same as the blowing-engines, and will develop 2500 brake horse-power when running at a speed of 75 revolutions per minute. The generator will be a direct-current machine of 1500 horse-power, and will be connected in parallel with the rest of the power machinery of this plant. At the Homestead Works there will be four blowing-engines, each consisting of a horizontal twin tandem double-acting Allis-Chalmers gas-engine of 3000 horse-power, having two blowing cylinders with a capacity of 30,000 cubic feet of free air per minute against a pressure of 20 lbs. to 25 lbs. per square inch.

A description is given * of eight large gas-driven blowing-engines to be installed at the Indiana Steel Company's new plant at Gary. Blast-furnace gas will be used, and the horse-power developed by each engine will be 3000.

Blast-Furnace Gases.—F. B. Wheeler † discusses modern problems in gas engineering, with special reference to the utilisation of waste gases from blast-furnaces.

K. Jurisch ‡ notes the occurrence of hydrocyanic acid in furnace gases.

F. E. Junge § discusses the economics of blast-furnace gas utilisation in steel and iron works, discussing the relative advantages of gas and steam-driven central stations, from examples drawn from actual practice. He gives a number of calculations bearing on the subject, including those relating to expenditure for maintenance, attendance, upkeep, and fuel expenses, and institutes a comparison in the cost of gas and steam driving in central stations, with special reference to the results obtained in rolling-mills.

A detailed description, with illustrations, has appeared || of the Oechelhauser gas-engine, for use with blast-furnace gases.

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* *Iron Age*, vol. lxxviii. p. 205; *Iron Trade Review*, July 26, 1905, pp. 17–21.

† *Engineering News*, vol. lv. pp. 33–34.

‡ *Chemiker Zeitung*, vol. xxx. pp. 393–394.

§ Paper read before the American Institute of Electrical Engineers, New York; *Iron Age*, vol. lxxvii. pp. 1392–1393, and 1462–1463.

|| *Engineering*, vol. lxxxi. pp. 5–8, 73–76, 141–144, and 204, with seventy-four illustrations.

A gas-washing plant, in which steam is used to separate dust and impurities, is figured and described.*

The apparatus patented in America for cleaning blast-furnace gas by means of steam † is based on the fact that the gas is mixed in vertical cylinders with steam, which takes up the mechanically admixed impurities. On condensation of the steam these are precipitated.

F. E. Junge ‡ describes the gas-cleaning plant of the Lackawanna Steel Company.

An illustrated description is given § of a new type of cleaner for blast-furnace gases, to be known as the Meehan cleaner. The gas is conducted through a series of water-sealed chambers and made to impinge on a number of baffle plates.

An illustrated description has appeared || of the dust catchers, which are an important feature of the Parkgate Company's new blast-furnace plant. They have been designed by F. W. Dick. Cones and separating screens are used, which not only secure the advantages of changes in velocity and direction, but also so dispose of the dust separated that it does not again come in contact with the gas currents but falls into a receptacle free from gas currents, from whence it is removed by gravity, in a dry condition. Separation of 85 per cent. is thus secured, and the danger of clogging, which takes place in wet separation, is avoided.

Appliances for cleaning blast-furnace gases, exhibited at the recent Liége Exhibition, are figured and described by L. Bréda,¶ with special reference to the Bian system. The advantages possessed by the Bian system he enumerates as follows: (1) It is possible to completely cool and clean the gases; (2) the cost of maintenance is trifling; (3) only a small amount of power is required to work the apparatus; (4) it is both simple and strong; (5) the consumption of water is small, and any source can be employed, even dirty water; (6) the gas is cooled, no matter what its initial temperature. A list of works using the Bian cleaner is given.

F. E. Junge ** describes a new source of profit in connection with gas-engines, namely, the production of nitric acid as a by-product of

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* *Iron Age*, vol. lxxvii. p. 1838.

† *Bihang till Jernkontorets Annaler*, 1906, pp. 339–341.

‡ *Iron Age*, vol. lxxviii. pp. 542–545.

§ *Iron Trade Review*, July 26, 1906, pp. 25–26.

|| *Iron and Coal Trades Review*, vol. lxxiii. p. 1171.

¶ *Revue Universelle des Mines*, vol. xiii. pp. 37–41.

** *Cassier's Magazine*, vol. xxx. pp. 348–353.

the explosive combustion and its attendant reactions. The process has been worked out by Häusser.

Direct Castings from the Blast-Furnace.—W. H. Butlin [*] gives the results obtained by mixing ores of different compositions, showing that as good results can be obtained as with a cupola.

Pig Breaker.—G. Rietkötter [†] briefly describes and illustrates several types of pig-breaking machines, including those worked by electric and hydraulic power.

German Blast-Furnaces.—C. Haening [‡] describes the new Hohenzollern blast-furnace works at Emden.

Hungarian Blast-Furnaces.—In a copiously illustrated monograph on the Vajdahunyadi iron-mines and works, G. Latinak [§] gives dimensioned drawings of the various blast-furnaces.

Russian Blast-Furnaces.—P. Thomas [||] describes the rebuilding of blast-furnaces at the Kramatorskaja Works in Southern Russia. He states that the ores used come almost entirely from the Krivoi Rog, from 50 to 55 per cent. of the ore charge consisting of red hæmatite with from 63 to 65 per cent. of metallic iron, 4 to 5 per cent. of silica, with about 30 per cent. of fine ore. Some 15 per cent. of the ore is in an intermediary stage between red and brown ore, and contains 59 per cent. of iron and 5 per cent. of silica; another 15 per cent. is a rich brown hæmatite with some 50 per cent. of fine ore; a fourth ore smelted contains 55 per cent. of iron and 11 per cent. of silica, the iron being present as magnetic oxide. A siliceous material, consisting of a ferruginous quartzite, with some 40 per cent. of silica and 40 per cent. of iron, is also used. The limestone employed comes from the Carboniferous formation, and contains some 2 per cent. of silica and 52 per cent. of lime; whilst the coke is from adjacent collieries of the Donetz basin, with 10 per cent. of ash and 1·5 per cent. of sulphur, and is of average strength. The furnace used in smelting this charge is described.

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[*] *Cassier's Magazine*, vol. xxx. pp. 239–245.

[†] *Stahl und Eisen*, vol. xxvi. pp. 1068–1069, with four illustrations.

[‡] *Giesserei Zeitung*, vol. iii. pp. 371–397.

[§] *Banyaszati es Kohaszati Lapok*, vol. xxxix. pp. 203–242.

[||] *Stahl und Eisen*, vol. xxvi. pp. 598–602, with seven illustrations.

American Blast-Furnaces.—G. Rivière* deals with American blast-furnace practice, and notes its chief points of contrast with European blast-furnace practice. He sketches the development of American blast-furnace design during the last twenty-six years, and shows the progress which has been made in the size of the furnace, and the increased production. The Gayley dry-air blast is briefly discussed.

The Northern Iron Company's blast-furnace at Port Henry, New York, is described by J. H. Granbery.†

The blast-furnace plant of the Federal Furnace Company, Chicago, is figured and described.‡ There will be two furnaces, although at present only one is in course of erection. The furnaces will be of 350 tons daily capacity, 75 feet high, 11 feet diameter at the hearth, and 18 feet 6 inches at the bosh. Each has four Kennedy two-pass hot-blast stoves, 75 feet high and 20 feet diameter, with central combustion chambers. Gas-washers are placed between the furnace and the stoves. The blast is distributed through eight tuyeres, and the top is fitted with the Kennedy closed top and distributing hopper. Each furnace will have a single charging skip of 120 cubic feet capacity, running in a tubular incline 7 feet diameter, built up of steel plate. The skip has a cylindrical body, and runs on rails of 4-feet gauge. The plant is on the bank of the Calumet River, and has a stock-yard served by two Brown travelling bridges 360 feet long. The casting-house is 65 feet by 220 feet, and has an hydraulic pig breaker. The blast is supplied by three vertical compound condensing blowing-engines, with steam cylinders 44 inches and 84 inches diameter, 84-inch air cylinders and 60-inch stroke.

A description has appeared§ of the plant of the Indiana Steel Company, an auxiliary of the United States Steel Corporation. The works will cover 1300 acres, at the south end of Lake Michigan, and will consume, when in full working order, about 5,000,000 tons of ore yearly. There will be sixteen blast-furnaces of 450 tons capacity each. A large coke-making plant, with by-product ovens, will be built. The blast-furnace gas will be used in large gas-engines driving electric generators, which will furnish current for motors operating all the machinery. A harbour and ore wharf must be built for the unloading of ore from the modern 600-feet lake ore steamers, and as the lake

* *Bulletin de la Société des Ingénieurs Civils*, 1906, No. I. pp. 351–366.

† *Engineering and Mining Journal*, vol. lxxxii. pp. 98–102.

‡ *Iron Age*, vol. lxxviii. pp. 135–138.

§ *Engineer*, vol. cii. pp. 340–341.

is very shallow for about half a mile from the beach, a channel will be excavated 250 feet wide, 27 feet deep, and nearly a mile in length. The blast-furnaces will be fitted with the Baker-Neumann rotary distributor, which consists of a small bell directly above the main bell or spreader in the head of the furnace. As each charge is dumped from the charging bucket it falls upon the small bell, which then drops, allowing the ore to fall into a hopper, the bottom of which is closed by the main bell. The small bell then rises and is revolved about 80 degrees on a vertical axis before it comes to rest, so that the next load is delivered in a different part of the hopper. The successive loads therefore fill this hopper uniformly, and when full the main bell is lowered, discharging the contents into the furnace. There will be at first eight gas-driven blowing-engines, each of 3000 horsepower when working on blast-furnace gas. There will be Westinghouse horizontal engines, with two 42-inch gas cylinders side by side, and tandem with a single 68-inch blowing tub or cylinder; the stroke is 54 inches. When running at 75 revolutions per minute the capacity of air delivery is 33,000 cubic feet of free air per minute at 18 lbs. pressure, with a maximum pressure delivery of 30 lbs. per square inch. Similar engines, but running at 85 revolutions, will drive the electric generators.

Béla Barlai * gives analyses of American iron ores and of the coke employed. The daily production of a blast-furnace is from 500 to 600 tons, and in many cases 700 tons of pig iron. The blast is heated to 550 to 590° C. Constructional details of the furnaces are given, with particulars of the Duquesne Ironworks and the Eliza Ironworks at Pittsburg, Ohio Steel Company, and the latest blast-furnaces of the Cleveland Furnace Company.

History of Iron.—Some of the machines described by Leonardo da Vinci (1452 to 1519) in the "Codice Atlantico" reproduced by the Academia dei Lincei, are illustrated by T. Beck.†

M. Hajnal ‡ publishes an article on the metallurgical labours of Vanoccio Biringuccio, the energetic and inventive engineer of the sixteenth century.

A. Müllner § traces the historical development of the mining and metallurgical industries of the Alpine countries. A tomb of an ironmaster dated 1537, in the church of St. Martin, reproduced in the paper, is the oldest monument of the kind in Austria. The ancient hammer works at Saverstnik near St. Martin, at Passiek, and at Sibenegg near Rattsach, are described.

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* *Banyaszati es Kohaszati Lapok*, vol. xxxix. pp. 337–355.

† *Zeitschrift des Vereines deutscher Ingenieure*, vol. l. pp. 524–531, 562–569, 645–651, 777–784.

‡ *Banyaszati es Kohaszati Lapok*, vol. xxxix. pp. 453–458.

§ *Berg- und Hüttenmännisches Jahrbuch der k. k. Montanistischen Hochschulen*, vol. liv. pp. 167–202.

In another paper, A. Müllner * points out that the metallurgical activity of the Etruscans is shown by the remains of the ironworks at St. Michel near Hrenowitz, and describes the various objects found by him in his excavations.

An account is given by A. von Pantz † of the Innerberger ironworks industry in the Erzegebirge during the years 1625 to 1783. The ores were obtained from the Vordernberg and Innerberg mines, and they were smelted on the spot, the product being sent in part to Leoben and in part to Steyr and thence along the trade routes. The Vordernberg or Leoben iron went in the direction of Vienna over Semmering and along the Drau valley and elsewhere, reaching Salzburg, Tyrol, Bavaria, and Switzerland, chiefly in a relatively southern direction, whilst the Innerberg or Steyr iron took a more northerly route, to Northern Germany, the Netherlands, and by sea thence to England and Spain. This had the Danube as a main trade route. The author deals with the local trade conditions of the period in question, and gives statistics showing that the production in 1629–1630 reached a maximum of 82,000 cwt. of iron, varying from that to 68,000 during the remainder of the seventeenth century.

L. Beck ‡ deals at some length with C. Wilkins' history of the iron and kindred trades in Wales, giving an interesting review of the rise and progress of the iron industry in particular.

The early history of the John Cockerill Works at Seraing is described by E. Mahaim.§

W. Hoesch || publishes an illustration of the Lendersdorf Ironworks in 1838. They were founded by his grandfather, Eberhard Hoesch, who at the suggestion of S. Dobbs went to England in 1823 to study the Cort method of puddling then introduced. Engaging himself as a workman he studied the process, secured skilled workmen, and with their aid established the Lendersdorf Works in 1838. The author

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* *Zeitschrift des Oesterreichischen Ingenieur- und Architekten-Vereines*, vol. lviii. p. 204.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 314–318.

‡ *Stahl und Eisen*, vol. xxvi. pp. 861–868, 932–938, and 1123–1131.

§ *Revue Universelle des Mines*, vol. xii. p. 171.

|| *Stahl und Eisen*, vol. xxvi. pp. 1256–1257, with one illustration.

gives data as to the prices for iron ruling in Germany at various dates from 1814.

E. Crandall * deals with the history of iron-mining and manufacture in the Hanging Rock District, Kentucky. The oldest furnaces in the district were the Junior furnace and the Franklin furnace, the latter of which was built in 1827. In 1880 there were thirty-one charcoal furnaces and seventeen furnaces using bituminous coal, but ten years later there were only eleven charcoal furnaces and fifteen bituminous coal furnaces, and this number has still further decreased. An output of 5 tons daily per furnace was good practice in 1844, and the increase in the year following to 8 or 9 tons daily at Junior furnace excited much interest in the district. In 1845 the boilers at the Mount Vernon furnace were placed at the top of the stack in order to utilise the furnace gases for generating steam.

M. A. Pavloff † has issued, in Russian, a pamphlet of 140 pages, summarising the literature of iron and steel published in 1905.

Numerous biographies of leaders of the iron and steel industries have been published: in *The Naturalist* for May of Dr. H. C. Sorby; in *The Timber News and Sawmill Engineer* (September 29, 1906, p. 36) of Allen Ransome; in the *Iron Trade Review* of Dr. R. W. Raymond (October 4, 1906, p. 29); in *The Iron and Steel Trades Journal* of W. F. Osborn (vol. lxxix. p. 374); in *Page's Weekly* of Walter Somers (vol. viii. p. 1387), F. Osmond, P. Eyermann, Sir W. Lloyd Wise, William Beardmore, E. Windsor Richards (vol. viii. pp. 1089–1091), Sir Hugh Bell, Bart. (vol. ix. p. 337), E. Matheson (vol. ix. p. 681), Percy C. Gilchrist, F.R.S. (vol. ix. p. 753); in *The Machinery Market* of W. Ridley Makepeace (Aug. 3, 1906, p. 11), R. Armitage (July 6, 1906, p. 11); in *Cassier's Magazine* of Mark H. Robinson (vol. xxix. p. 2); in *Syren and Shipping* (Supplement, August 1, 1906) of Sir Hugh Bell, Bart., Tom Westgarth (vol. xl. p. 283), R. A. Hadfield (Supplement, June 6, 1906), and the late Sir Edward J. Reed (vol. xxxix. p. 361).

II.—*CHEMICAL COMPOSITION OF PIG IRON.*

Hungarian Pig Iron.—The Resicza works produce grey Bessemer pig iron (I.) and white open-hearth pig iron (II.), whilst the Anina works produce grey foundry pig iron (III.) and white forge pig iron (IV.). The chemical composition * of these pig irons is as follows:—

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* *Iron Trade Review*, July 12, 1906, pp. 20–22; July 19, 1906, pp. 20 23.

† St. Petersburg, 1906.

	I.	II.	III.	IV.
Combined carbon	0·03	3·09	0·22	2·50
Graphite	3·45	0·55	3·02	0·45
Total carbon	3·48	3·64	3·24	2·95
Silicon	1·07	0·48	2·16	0·42
Manganese	1·00	1·12	2·08	1·80
Phosphorus	0·08	0·09	0·05	0·05
Sulphur	0·01	0·04	0·01	0·03
Copper	0·06	0·06	0·07	0·06

Grading Pig Iron.—R. Meeks † suggests a method of grading American pig irons.

W. B. Parker ‡ discusses the advantages which would follow the general adoption of a system of specifications for pig irons from the point of view (1) of the composition and grading of the chief classes of pig iron already in use, and (2) of the composition and grading most suitable for the largest number of purposes, or for the largest individual demands. With regard to the first question, he divides the best known pig irons into four groups. In the first group, special pig irons, he includes South Staffordshire; cold blast (both English and Welsh); Swedish charcoal iron (hot and cold blast); and refined iron. In group 2 he includes North Staffordshire, Derbyshire, Lincolnshire or Frodingham, Northamptonshire and Cleveland or Middlesbrough ordinary pig irons. These all contain high phosphorus percentages (1 to 1·5 per cent.), fairly low sulphur, and can be further subdivided into two groups, X and Y, according to whether the manganese is below or above 0·75 per cent. The third group consists of the well-known brands of Scotch pig irons such as Glengarnock, Carron, Gartsherrie, and Summerlee, and others. The fourth and last group consists of hæmatite pig irons, whether English, Scotch, or Welsh. Reverting to the first group, he takes each subdivision and assigns the ideal chemical composition, the limits of which should not be exceeded in respect to either of the three constituents, phosphorus, sulphur, and manganese. In this connection he discusses the category in which cylinder mixture, of which Goldendale is typical, should be placed, and inclines to the view that it should be regarded as belonging to group 2. Having classified the pig irons in respect to their percentages of phosphorus, sulphur, and manganese, he next considers them in relation to the carbon and silicon they contain, and, after pointing out that grading by fracture is antiquated, and really depends upon the relative hardness and size of graphite plates, he discusses the first-named property in the light of researches by Howe, Turner, and others. He summarises the influence of the constituents as (1) softness, and (2) hardness, placing silicon alone in the first category, and the remaining constituents in the second. The size of the graphite is chiefly influenced by the rate of cooling, hence many considerations need to be taken into account. On the other hand, the percentage of combined carbon depends on the amount of silicon present. He comes to the conclusion that grading should depend upon the amount of combined carbon and of silicon present, the quality of the pig iron being determined by the amount of phosphorus, sulphur, and manganese it contains. Diagrams and tables are given, illustrative of the chief points described, group 2 being exemplified by the specifications shown as curves after the method of W. H. Pretty, known as " brand characteristic or curve." In the discussion which followed the reading of the paper, it was generally conceded that a system of standard grading and specification was greatly needed.

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* *Stahl und Eisen*, vol. xxvi. p. 1364.

† *Engineering and Mining Journal*, vol. lxxxi. p. 808.

‡ Paper read before the British Foundrymen's Association; *Iron and Coal Trades Review*, vol. lxxii. pp. 2305–2308.

III.—*BLAST-FURNACE SLAGS.*

Constitution of Slags.—In a paper on the lime-silica series of minerals, A. L. Day * and E. S. Shepherd show that the method used by Boudouard † to determine the constitution of such minerals was a very inaccurate one. There are only two definite compounds of lime and silica capable of existing in contact with the molten materials under furnace conditions—the pseudo-hexagonal metasilicate, melting at 1512°, and the orthosilicate of calcium, which melts at 2080° and possesses α, β, and γ forms. The orthosilicate is readily attacked by water.

Utilisation of Slags.—Blast-furnace slags are discussed by O. Boudouard.‡ He observes that the production of a ton of pig iron is accompanied by the production of 1⅙ ton of slag, and that the annual production of blast-furnace slag amounts to at least 60,000,000 tons. He enumerates the uses to which such slags are put, and divides them into two classes, (1) silicate slags, and (2) non-silicate slags. He discusses the fusibility, melting-point, and viscosity of slags, and their influence on the character of the metal produced.

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* *American Journal of Science*, vol. xxii. pp. 265–302.

† *Journal of the Iron and Steel Institute*, 1905, No. I. p. 339.

‡ *Revue Genérale de Chimie pure et Appliqué*, 1906, p. 137; *Génie Civil*, vol. xlviii. p. 455.

W. McA. Johnson [*] describes an apparatus for ascertaining the melting-point of slags, by which he claims to have secured results agreeing with each other within 5° C.

A new form of slag truck, specially designed to withstand rough usage, is figured and described.[†] Its capacity is 10 to 15 tons of slag, and is provided with the necessary arrangements for tipping and tilting.

Blast-Furnace Slag Cement.—In a report [‡] of the work done in the laboratory of the German Association of Iron Portland Cement Manufacturers, it is shown that the average results of the Association's investigations in 1905 as to the relative value of the cement made with blast-furnace slag—iron Portland cement—and ordinary Portland cement, resulted in the former being found to be of equal value to the ordinary cement, as the following table shows:—

	Portland Cement.	Iron Portland Cement.
Specific gravity as delivered	3·036	3·001
Weight per litre in grammes—		
Loose	1137	1099
Shaken together	1743	1565
Binding period	6 h. 47 m.	6 h. 10 m.
Water addition, 1 : 3	8·65 per cent.	8·10 per cent.
Crushing strength, 1 : 3, 28 days	536·4 lbs.	605·4 lbs.
Tensile strength ,, ,,	47·6 lbs.	50·1
Ratio of tensile strength to crushing strength	1 : 11·3	1 : 12·4

The plant for manufacturing blast-furnace cement, installed by the Struthers Furnace Company, Struthers, Ohio, is described.[§] The slag is brought from the blast-furnace in steel hopper trucks. The approximate composition is: Silica, 31 to 34 per cent.; alumina, 12 to 15 per cent.; lime, 46 to 49 per cent.; sulphur (extreme limit), 1·3 per cent

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[*] *Electrochemical and Metallurgical Industry*, vol. iv. pp. 262–263.

[†] *Iron Age*, vol. lxxvii. p. 1389.

[‡] *Stahl und Eisen*, vol. xxvi. p. 1145.

[§] *Iron Trade Review*, June 28, 1906, pp. 17–20.

Adjoining the blast-furnace are two circular pits about 25 feet in diameter and 10 feet to 15 feet deep. Into one of these pits slag that is suitable for cement manufacture is run, and into the other the slag which has to be disposed of as waste product. As the slag runs from the gutter into the pit, it falls through a spray of water which flows from a 4-inch pipe, the end of the pipe being flattened to discharge the water in a wide, flat spray. This granulates the slag into comparatively small pieces, which are easily passed through a shoot into a battery of dryers. These two dryers are of different sizes, one being 72 inches in diameter by 36 feet, and the other 52 inches in diameter by 30 feet in length. The smaller one is set on an incline to facilitate the passage of material from one end to the other, and the larger is provided with flights on the interior, which serve the same purpose. A coal fire built in the furnace at one end expels all the moisture from the slag. The gases pass completely through the dryer and out of the stack situated at the receiving end. The red hot slag leaving the dryer drops into a screw conveyor which moves it to the opposite side of the building, whence it is elevated to the roof trusses and carried along by another screw conveyor which delivers it into Griffin mill bins.

L. Jesser * discusses the relations which exist between the hydraulic properties and chemical composition of blast-furnace slag employed in the manufacture of cement.

IV.—*FOUNDRY PRACTICE.*

Cupola Practice.—C. Rein † discusses the conditions to be considered in the construction of foundry cupolas.

L. Bréda ‡ describes the exhibits relating to foundry practice shown at the recent Exhibition at Liége. They include the Lepourc cupola, which is designed to save fuel, and can maintain its charge in a very hot condition with an expenditure of only 5 to 6 per cent. of coke. It possesses the further advantage of being very regular in working, and of avoiding scaffolding, as well as being very readily charged.

W. H. Coleman § advocates low pressure in cupolas, but not scanty volume or supply of air. Many foundrymen are using blowers far below the required capacity in volume; therefore they are compelled to speed up their blowers in order to get the necessary volume, thereby getting, incidentally, higher pressures than are needful. Speaking generally, he considers that less pressure is required for coke than for coal, but more volume. A larger tuyere area is required for coke than for coal, but coke more rapidly becomes chilled by high velocity or pressure. Tuyeres and lining will not burn out so quickly under the low blast pressures, while too much air will reduce the temperature of the gases and retard combustion, particularly when introduced in top row of tuyeres. The blast should be started at low pressure, and increased up to the maximum pressure required during the heat. The pressure should be lowered again at the end of the heat, for the reason that having less metal in cupola and more space around it, oxidation of silicon in the iron and the consequent hardening of the castings is prevented. Choked tuyeres are prevented by having large tuyere area with plenty of volume at low pressure, good iron and good fluxing. Blast pressure is advisable, provided that the cupola is large enough to give the required melting capacity, and provided that the blast pressure is not reduced enough to make melting unreasonably slow.

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* *Chemiker Zeitung*, vol. xxx. p. 225.

† *Giesserei Zeitung*, vol. iii. pp. 417–449.

‡ *Revue Universelle des Mines*, vol. xiii. pp. 41–46.

§ *Transactions of the American Foundrymen's Association*, 1906, pp. 142–150.

N. W. Shed* has constructed a foundry furnace in which two chambers are introduced between the furnace and the stack, in which the products of combustion are utilised for pre-heating the air.

N. W. Shed† considers limestone the most suitable flux for the cupola. It can be employed in any form, only it must contain at least 51 per cent. of lime. Three per cent. of silica renders it useless. The percentage of sulphur should not exceed from 1 to 2 per cent. The quantity of flux employed depends on the percentage of silica in the coke ash, the quantity of sand with the pig iron, and on the percentage of silica desired in the slag. A monosilicate is recommended, which contains equal quantities of silica and alkalies. With coke of average quality, a good measure for the addition of lime is 25 per cent. of its weight in the charge. The appearance of the slag indicates the working of the furnace. Light brown slag indicates that the furnace is working satisfactorily, and that there is little iron in the slag. Black slag indicates considerable waste. All cupola slags which are melted with an addition of limestone have a lustrous appearance, and all that are melted without an addition of limestone are dull and earthy. The composition of two slags, one with and the other without an addition of limestone, is as follows:—

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* *The Foundry*, vol. xxvii. p. 227.

† *Ibid.*, vol. xxviii. pp. 319–321.

	With Limestone.	Without Limestone.
Lime	34·60	6·60
Ferrous oxide	4·10	21·76
Alumina	11·02	11·80
Silica	48·20	58·44
Manganese oxide	1·40	1·30
Sulphur	0·20	0·10
	99·52	100·00

Foundry Appliances.—The Piqua positive blower is described and illustrated.* It is specially designed for foundry, forge, and oil furnace service, and for purposes requiring a positive supply of air under pressure of 12 lbs. per square inch or less.

An illustration is published † of a table for the cleaning of castings, devised by a German firm. Through the bars forming the top a constant current of air is drawn downwards into a sheet-metal receptacle below. In this way the formation of dust is avoided, and the sand collected in the receptacle can be removed by clap doors.

Foundry Mixtures.‡—Bradley Stoughton discusses the influence of foundry mixtures upon the shrinkage and porosity of castings, and on their softness, workability, and strength. The effect of the presence of manganese and sulphur in causing a casting to check is also briefly investigated.

J. Mehrtens, jun.,§ observes that of late it has become common to hear the remark, in connection with the manufacture of machinery, that it is cheaper to buy foundry iron than to make it oneself. This the author disputes, dealing with questions of costs and time arrangements within the works, as well as with other matters. It is surprising, he observes, to note the great variations in price in foundry tenders. This, he thinks, is largely due to errors in the methods of calculation that are in use at foundries. Monthly cost returns ought to be kept at every foundry.

The calculations involved in foundry practice are discussed by O. Lippmann.||

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* *Iron Age*, vol. lxxvii. pp. 1908-1909.

† *Stahl und Eisen*, vol. xxvi. p. 1138.

‡ *Iron Trade Review*, November 15, 1906, pp. 25-28.

§ *Stahl und Eisen*, vol. xxvi. pp. 1062-1067 and 1132-1137.

|| *Giesserei Zeitung*, vol. iii. p. 205.

Importance of Chemistry in Foundry Practice.—Max Orthly [*] draws attention to the great importance of the chemical control of purchased brands of pig iron, and specially draws attention to the misleading indications of the grain alone. He says that the grain plays an important part in the purchase of pig iron. Frequently a certain chemical composition is specified in the contract; the buyer only considers the price, and selects the quality on the ground of the specified composition without controlling the same. That the sellers know exactly which firms do not analyse their pig iron is perfectly clear. Loads of pig iron are often supplied to these firms which satisfy the specification very well according to appearance, but much less according to chemical composition. The author confirms this affirmation by giving numerous analyses, and at the same time examples showing how defective castings can in the circumstances be produced.

Carl Rott [†] refers to the great difference between former and present practice in the foundry, and at the same time lays stress on the necessity for the practical man to keep well informed of the results of metallography. He then refers to the experimental smelting at the Friedrich-Wilhelmshütte, Mülheim on the Ruhr, and the metallographical, chemical, and magnetic researches of Nathusius. The object of these experiments was, in the first place, to demonstrate by what additions or mixtures in the iron the magnetic properties were mostly influenced, and how far they are in relation to other properties of cast iron. The accompanying table on the next page is compiled by the author from the results of these experimental meltings.

Ferro-Silicon in the Foundry.—A. E. Outerbridge, jun., [‡] advocates the employment of high-grade ferro-silicon in the foundry in order economically to obtain a variety of grades of molten iron suitable for different kinds of castings from one cupola in one heat. He describes experiments made in this direction, by which 98 per cent. silicon was added without success, owing to its lightness and its high melting point. On the other hand, 50 per cent. ferro-silicon, powdered and either sprinkled with the stream of molten metal when passing into the ladle, or added to the ladle preparatory to casting, yields excellent results. Tensile strengths of a number of specimen bars are given.

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[*] *Metallurgie*, vol. iii. pp. 446–456.

[†] *Eisen-Zeitung*, vol. xxvii. pp. 472, 490.

[‡] *Transactions of the American Foundrymen's Association*, 1906, pp. 5–9.

No. of the Iron Brand.	Chemical Analysis.						Specific Gravity.	Load on the Square Centimetre.	Specific Resistance per sq. mm. in Ohms.	Magnetic Induction. C. G. S.		Permeability. C. G. S.		Remarks.
	Combined C.	Graphitic C.	Si.	Mn.	P.	S.								
24	0	1·691	6·230	0·381	0·109	0·022	7·213	...	1·053	13·790	165·7	2125	1·8	Best to not good.
18	0·485	1·819	6·140	1·458	0·119	0·040	7·205	15·14	...	11·460	154·6	1897	1·67	
4	0·520	1·870	5·554	1·438	0·139	0·078	7·116	25·20	1·506	11·410	143·7	1503	3·00	
1	0·549	2·476	3·658	0·494	0·138	0·060	7·013	27·06	1·098	11·350	152·4	719	2·135	
VIII.	0·620	2·896	1·415	0·999	0·656	0·106	7·064	...	...	9640	147·1	290·2	7·36	Bad.
V.	0·180	2·566	1·24	0·68	0·890	0·067	7·043	...	...	8356	165·7	151·1	19·8	
I.	0·490	3·34	1·88	0·82	0·082	0·020	7·209	...	...	7664	146·6	350·2	3·3	
VII.	0·331	3·305	2·327	0·278	2·232	0·324	6·79	...	...	7496	152·3	222·5	5·5	
II.	0·86	2·90	2·25	0·49	0·059	0·043	7·225	...	...	7149	150·1	284·0	5·271	
IX.	0·897	2·329	1·311	0·360	0·073	0·160	7·023	...	...	6561	154·8	210·8	7·5	
0	0·785	2·659	2·451	5·407	0·016	0·161	7·226	24·96	1·316	6501	150·2	61·0	59·7	Special.

No. 24 is the iron with the best magnetic properties.

British Foundries.—A description has appeared * of the workshops and foundries of Scott's shipbuilding and engineering works at Greenock.

German Foundries.—E. Guarini † describes the foundries and workshops of the Vereinigte Maschinenfabrik Augsburg und Maschinenbaugesellschaft Nürnberg. The works occupy an area of 66¼ acres, of which 19¾ are covered with buildings. The main iron foundry is equipped with two furnaces of the crucible type, capable of furnishing ten castings a day each, and three ordinary cupolas. There is a second foundry containing five cupolas of varying capacity, the largest holding about 7½ tons of metal, the aggregate capacity of the cupolas of this foundry being 16 tons.

E. Freytag ‡ describes foundry plants which have been erected in Germany during the past five or six years. Considerable progress, he says, has undoubtedly been made of late in foundry practice, and he discusses this subject generally. The cupolas employed are now mostly of the Krigar type with fore-hearth, although the older Ireland type is also frequently in use at smelting-works. The output of the Herbertz cupola is too low, with the result that it is not largely employed. The consumption of coke usually varies from 9 to 12 per cent. A consumption of from 6 to 9 per cent. is guaranteed by those who supply the cupolas, but in practice a higher percentage is needed. The use of hot blast has been said to cause a reduction in the coke consumption, but further information on this point is needed. The height of the cupola shaft should never, the author considers, be less than about 20 feet 9 inches, and is often much too low. The loss in the cupola is usually from 5 to 8 per cent., a large proportion of which is no doubt due to the sand adhering to the pig iron charged. Reverberatory furnaces are now less used than was formerly the case owing to their greater fuel consumption, and of the foundries described by the author only two have them. The drying chambers are often the cause of the consumption of 50 per cent. more coke than is used in the cupolas, their construction and method of operation being primitive. Some foundries use dried moulds but little, while others employ these to a far greater extent. They usually take up from 5 to 15 per cent. of the area of the foundry. The castings are cleaned at times in the foundry itself, and at others often in a building at a considerable distance. It should be as near as possible. The cranes in use are also dealt with, and then the author describes a number of foundries separately. It is customary in Germany to calculate the annual output of a foundry at from 0·8 ton to 2·5 tons per square metre (10·8 square feet) of area, though it is sometimes about 4 tons.

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* *Engineering*, vol. lxxxi. pp. 171–172.

† *Iron Trade Review*, March 15, 1906, pp. 17–18.

‡ *Stahl und Eisen*, vol. xxvi. pp. 738–742, 810–814, and 872–875, with sixteen illustrations.

G. Rietkötter * describes and illustrates a recently erected foundry plant, intended mainly for making heavy machine castings up to 50 tons in weight. Electro-motors are used throughout for driving purposes, receiving their power from a central electric lighting and power plant. There are four cupolas, and of these three are placed in a row at a height of 63 inches above the floor. This is to avoid the use of a casting-pit. A fifth is projected. The three cupolas above referred to are in constant use, one or two being in operation as needed. The average production of iron per day is 100 tons, but sometimes the molten metal reaches half as much again. A charge consists of half a ton of iron, with 8 per cent. of coke and 3 per cent. of limestone. Details as to these cupolas are given, and generally the whole plant used at the foundry is passed in review. The workpeople employed number 250.

Italian Foundries.—An illustrated description has appeared † of the new foundry of the Franco-Tosi Works, Legnano. The works, which at present employ 1600 hands, cover 80,000 square metres, while the area of the new foundry itself is 10,000 square metres. It is furnished with three cupolas of 8 tons capacity each, and one of 3 tons.

American Foundries.—The equipment of new foundries in North America is described by E. L. Pettersson. ‡

The new shops and foundry of the Ernst Wiener Company, Youngstown, Ohio, are described. §

The new foundry and workshops of the Allis-Chalmers Company,

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* *Stahl und Eisen*, vol. xxvi. pp. 546–551 and 615–621, with two plates and six illustrations in the text.

† *Engineer*, vol. ci. pp. 492–493.

‡ *Teknisk Tidskrift, Mekanik och Elektroteknik*, vol. xxxvi. pp. 134–136.

§ *Iron Age*, vol. lxxvii. pp. 1896–1898, with three illustrations.

Milwaukee, are figured and described.* The foundry is 994 feet long and 222 feet wide.

The plant of the Manufacturers' Foundry Company, Waterbury, Connecticut, is illustrated and described.† The main foundry is 225 feet long and 80 feet wide, and is served by a 10-ton travelling crane. The works are employed in the manufacture of exceedingly intricate castings, and the composition of the core mixtures therefore requires very careful adjustment to suit the character of the castings made. The metal is supplied by a No. 5 Whiting cupola, blown by a No. 9 Sturtevant fan.

The new plant of the Traylor Manufacturing and Construction Company, Allentown, Pennsylvania, is described.‡ The foundry is 285 feet long and 100 feet wide, and is equipped with three large cupolas, one of which can melt sufficient metal for castings up to 2½ tons, while the aggregate capacity of the foundry will be 40 to 50 tons of castings per day.

Reverberatory Practice in American Foundries.—V. Portisch,§ of the Garrison Foundry Company, Pittsburg, deals with the use made of the reverberatory furnace in foundry practice in the United States. Only a few works use them, as the advantages to be gained by melting down pig iron in them are dependent on certain narrow limits of practice. According to its size, such a furnace will yield per tap from 7 to 40 tons of perfectly homogeneous iron, which has but little more sulphur than the metal originally charged. By means of samples it can be kept continuously under control and its composition altered, and large pieces of cast scrap can be melted down in it. On the other hand, as compared with the cupola, there is an increased cost for wages, fire resisting materials, and usually for fuel as well. The loss of metal, too, is greater, and it needs much more careful manipulation. It is of especial advantage in connection with the manufacture of rolls, and the author observes there is probably now scarcely a single foundry which makes any large quantity of heavy rolls that does not employ the reverberatory furnace for the purpose. A number of other castings, too, which the author enumerates, in which quality is a matter of importance, are best made by the aid of the reverberatory furnace.

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* *Iron Trade Review*, April 12, 1906, pp. 17–20.

† *Ibid.*, April 19, 1906, pp. 17–20, with seven illustrations.

‡ *Iron Age*, vol. lxxvii. pp. 1836–1837.

§ *Stahl und Eisen*, vol. xxvi. pp. 1165–1171, with six illustrations.

The author illustrates and describes several such furnaces, and the practical results obtained in connection with their use.

Moulding-Sand.—E. L. Rhead * deals with sand-mixing appliances in the foundry, and gives several illustrations of sand sifters and mixers. †

A description is given ‡ of a self-propelling foundry sand-mixer driven by electricity. When in operation, the large or driving wheels advance the machine at such a rate that the rapidly rotating knives pass through the sand-heap at intervals of half an inch. Under favourable conditions one of these machines can cut up 100 heaps of sand, each 60 feet long, in ten hours. The machine, complete, weighs 650 lbs., and can mix core sand or facing sand at the rate of 10 tons per hour.

H. Fürth § deals with the properties that should be possessed by a sand that is to be used for moulding purposes, and how they should be estimated for any sample. Occasionally sand contains small quantities of magnesia, the alkalies, and organic substances; and the author deals with Field's investigation as to how these occur in the sand, and in what way they influence its properties. Both the latter and Ries consider the combined water to be the cause of the plastic properties of the sand. Lime and ferric oxide do harm by forming fusible silicates which clog the pores of the sand, whilst any carbon dioxide evolved when the sand is heated may destroy the surface of the mould. The use to which the sand can be put is in the main shown by the ratio existing between the silica and alumina. Thus Vinsonneau considers that for casting bronze the sand should contain not more than 10 per cent. of alumina, for cast iron 8 per cent., and for steel 5 to 7 per cent. Vinsonneau's rapid method for testing such sands is referred to and illustrated, and other methods are also given. These deal chiefly with the determination of the size of the sand particles, its porosity and fire-resistance. The author foresees the general use of standard methods, according to the results of which the sand will be valued, much in the same way as analysis is brought into play in the classification of the pig iron used in foundry practice.

H. Ries ‖ proposes standard tests for foundry sand, so that the use of a sand can be judged without expensive tests in practice. The author proposes that in testing and fixing the standards the following properties should be considered. (1) Fineness. The sand to be sifted through four different sieves, and the fractions to be weighed; (2) permeability and porosity; by the first is understood the faculty of allowing gases and fluids to pass through, by the last the proportion of quantity between real and apparent volume; (3) resistance to fire; (4) duration of use; (5) binding properties; and (6) chemical analysis. The sand should be free from lime, and contain not more than 3 per cent. of metallic oxides. The paper concludes with a comparative table of the composition of a large number of moulding and core sands.

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* *Mechanical Engineer*, vol. xvii. pp. 3–5, with ten illustrations.

† *Ibid.*, pp. 100-102.

‡ *Iron and Coal Trades Review*, vol. lxxiii. p. 1004.

§ *Stahl und Eisen*, vol. xxvi. pp. 1195–1197, with one illustration.

‖ *Foundry*, vol. xxviii. pp. 327–343.

A system of drying sand and loam moulds is described,* by means of which it is claimed that a saving of 90 per cent. of the fuel ordinarily used can be effected, while the time taken is also shorter.

E. D. Frohman † deals with sands and core compounds, giving the results of tests showing that the amount of loam in the sand determines what core binder must be used.

H. J. McCaslin ‡ describes multiple core moulding, a method specially adapted to small castings.

Moulding-Machines.—In reviewing recent progress in the metallurgy of iron, Bradley Stoughton § notes that in foundry practice the most important recent advances have been in connection with moulding, where progress has taken place along two lines, (1) the extension of the field for machine-moulding, as, for example, the installation of large hand-ramming machines for floor work, the extension of mechanical appliances, and the moulding of wheels, and (2) the use of permanent moulds, made of carbon or similar material. The second of these processes is still in the experimental stage.

E. V. Ronceray || describes present practice in machine moulding. He sketches hand moulding devices, and passes from that subject to the rotary moulding machine driven hydraulically. The Pridmore machine is then described, after which he gives details of a number of American machines, including those of the Tabor and Paxton-Hall type. The hydraulic machines of Bonvillain and Ronceray are

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* *Iron and Coal Trades Review*, vol. lxxiii. p. 1179.

† *Foundry*, vol. xxviii., June 1906.

‡ *Ibid.*

§ *Mineral Industry*, New York, vol. xiv. p. 352.

|| *Mémoires de la Société des Ingénieurs Civils*, 1906, No. I. pp. 952-990.

then described. It is pointed out that hitherto machine appliances of this nature have met with scanty attention from engineers and founders, and that the operations they are intended to fulfil offer great scope for engineering ingenuity, and are productive of great saving in foundry practice.

A. Lentz * deals with moulding machinery, and in particular with that devised originally by Saillot, and since extended and greatly developed by the firm of Bonvillain and Ronceray, France. Various types of this are illustrated and described.

L. Guillet † discusses the design and operation of moulding machines.

E. Baur ‡ describes and illustrates the various moulding machines made at the Wasseralfingen works.

A description is given § of a hydraulic moulding machine for moulding loose unparted patterns.

Moulding tools and appliances are dealt with by E. L. Rhead.||

E. L. Rhead ¶ has also written a series of articles on foundry moulds and their production.

Further notes by F. Schraml ** on foundry practice deal with moulding appliances of various types, the casting of pipes, columns, &c., the furnaces in use, foundry plans, and other matters, the subject being discussed generally at considerable length.

R. Fischer †† describes the preparation of foundry moulds and the materials used for the purpose.

R. H. Palmer ‡‡ describes two ways of moulding a heavy gap press body employed at a foundry at Warren, Massachusetts.

Electric Motors in Foundries.—H. S. Knowlton §§ deals with the application of electricity to foundry operations. Motors are employed for operating cranes, for handling material and making castings, while electric welding is also employed with success. He

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* *Stahl und Eisen*, vol. xxvi. pp 939–945, and 1006–1013, with thirty-five illustrations.

† *Génie Civil*, vol. xlix. pp. 19–23.

‡ *Zeitschrift des Vereines deutscher Ingenieure*, vol. l. pp. 1194–1196 and 1236–1243.

§ *Engineering*, vol. lxxxi. pp. 481–482.

|| *Mechanical Engineer*, vol. xvii. pp. 139–141, 247–249, with fourteen illustrations.

¶ *Ibid.*, pp. 338, 405, 481, 578, 662, 741, 792, 875.

** *Stahl und Eisen*, vol. xxvi. pp. 551–554, 673–676, and 742–744, with twenty-two illustrations.

†† *Giesserei Zeitung*, vol. iii. p. 193.

‡‡ *American Machinist*, vol. xxix. pp. 728–731.

§§ *Cassier's Magazine*, vol. xxix. pp. 389–397, with nine illustrations.

suggests the use of electro magnets for charging the cupola and for picking up the scrap and waste in the foundry.

The employment of electric cranes in foundries is discussed by H. Sawyer.[*]

H. A. Croxton [†] describes the equipment of a modern pipe foundry capable of producing 200 tons of finished pipe daily, or 60,000 tons per annum. The selection of the mixture is important, and a fair range of pig iron is advocated, preference being expressed for selection and mixture by analysis rather than by fracture. The precautions to be taken after casting receive special mention.

E. Freytag [‡] discusses the rebuilding and enlargement of old foundries.

David Townsend [§] describes the considerations to be adopted on building a new foundry. He compares the usual American with the European manner of construction, and attaches special importance on the consideration of the suitable selection of building materials, of effective lighting, heating, ventilating, and the practical power plant.

David Townsend [||] considers that electrical machinery is the best mode of working foundry appliances, although compressed air is in many instances found to be more economical.

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[*] *Transactions of the American Foundrymen's Association*, 1906, pp. 31–34; *Iron Age*, vol. lxxvii. pp. 1845–1846.

[†] *Iron Age*, vol. lxxviii. pp. 146–147.

[‡] *Giesserei Zeitung*, vol. iii. p. 366.

[§] *Foundry*, vol. xxviii., June 1906.

[||] *Iron Trade Review*, April 12, 1906, pp. 23–24.

PRODUCTION OF MALLEABLE IRON.

Native Iron-Smelting in India.—A native Indian iron-smelting furnace is described by C. M. Weld.* To build a furnace a shallow pit is first dug and a foundation is laid of clay. The stack is then built up of clay, mixed with a little straw or chaff, to a height of 40 inches, the shield in front rising some 6 inches higher. It is roughly semi-circular in plan, the straight front being 26 inches to 28 inches wide. The shaft has a diameter of 4 inches at the top and 9 inches at the boshes. The opening at the hearth is 8 inches by 8 inches, the front wall is 2 inches to 3 inches thick, and the side and back walls are 12 inches to 15 inches thick. A band of twisted withes near the top serves to hold the structure together. It takes about a week to complete such a furnace, and it will generally serve through one smelting season of eight months. To prepare the furnace for blast, it is first cleaned and repaired wherever the previous operation has made repair necessary. The hearth is then packed with fine, wet charcoal, and the tuyeres are placed in position. They are two in number, made of potter's clay, 8 inches long and about ½ inch inside diameter. They are placed slightly diverging inward and at a slight angle downward. The outer ends rest on an upright iron rod. The front of the hearth is then luted up with clay and finally smeared over with powdered charcoal. A board of triangular shape is next put in place, its three supports being a lug or projection on the iron tuyere rest and the two points of a forked stick, planted a foot or so back from the furnace. This board serves as a rest for the bellows. The furnace is now filled with charcoal, with a handful of iron ore on top, and live coals are blown in through the tuyeres. The bellows are then attached, all joints being carefully luted, the connection is weighted down with a stone and blowing begins. The bellows are made of untanned goat skin. They are two in number, cylindrical, and distended by means of bamboo rings. The top is left open and is gathered up and grasped by the hand in such a way as alternately to open and close the bag as it is extended and compressed. The two bags are drawn down at the lower end and fastened to a double clay nozzle, made to fit snugly into the outer ends of the two tuyeres. The bellows are about 10 inches in diameter and 15 inches long when stretched. The operator stands in front of the furnace, grasps a bag in either hand and alternately fills and expels, throwing his weight first on one, then on the other. Each bag is filled about fifty times a minute. Women as well as men take their turn, changing off every half-hour or so. When the furnace is once well in blast it is fed continuously with ore and charcoal, one handful of the former to two or three of the latter. This goes on till two small basketfuls of ore and two large basketfuls of coal have been consumed. The slag is removed from time to time by running a small rod into the luted hearth front. The puncture is in each case left open only a minute or two and is then luted up again. The first slag is generally drawn about half an hour after blowing in.

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* *Iron Age*, vol. lxxviii. pp. 668-669; *Engineer*, vol. cii. p. 332.

Iron-Smelting in China.—Iron in China is made by mixing four parts of the ore, one part of decomposed coal dust, and one part of small coal. The mixture is placed in crucibles each about 18 inches deep and 6½ inches in diameter. The crucibles are heated in a furnace having walls about 3 feet high and a floor 4 feet by 6½ feet, which is covered with clay and spread with a layer of coarse coal to a height of 7 inches or 8 inches above the clay. The furnace holds about sixty of these crucibles. The space between them is filled with small coal, and on top is placed a 3-inch layer of small coal, followed by a layer of cinders and ashes of the same depth. About sixteen hours' strong heating suffices to convert the mixture into a mass of carbon iron. This is made into wrought iron by re-heating over a wood fire, and by hammering it when red-hot.*

Reverberatory Furnaces.—According to Gustav Hofer † it is impossible to obtain metallic iron from iron ores in an ordinary reverberatory furnace, even with the aid of a reducing water-gas flame. The reduction requires an atmosphere consisting of 2½ volumes carbonic oxide and one volume carbonic anhydride. By mixing finely ground ore with coal the reduction can be considerably aided. Spongy iron is first obtained, and in order to melt it a temperature of 1700° C. and a slightly reducing flame are necessary. Two kinds of furnaces are described which satisfy these requirements. One of these is a double reverberatory furnace, in one portion of which the ore is reduced, and in the other the iron is smelted; the other is an ordinary reverberatory furnace provided with the necessary heating arrangements for both phases of the process. The paper is accompanied by illustrations of the furnaces.

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* *Engineer*, vol. cii. p. 371.

† *Giesserei Zeitung*, vol. iii. pp. 559–561.

Electric Smelting of Iron.—During the past half year much attention has been devoted to the electric smelting of iron and steel. Practical trials have been made with electric furnaces of various types, and a large amount of valuable literature has been published. Recent progress is well summarised by J. B. C. Kershaw.* He enumerates the chief works at which iron and steel are made by electrical methods, and discusses the production of iron alloys and nickel in the electric furnace.

A. Stansfield † describes the electric furnace, giving particulars of its evolution, theory, and practice.

The present position of the electric smelting of steel is reviewed by J. Thibeau.‡

Mariani § considers the production of pig iron and the refining of steel in the electric furnace, and the possibility of the introduction of electric methods in England.

J. W. Evans ‖ describes some laboratory experiments with an electric furnace.

J. Hess ¶ reviews the various processes of electro-metallurgy. The production of pig iron in the electric furnace owing to the cost of power has no advantage over former processes. The transformation of pig iron into Bessemer or open-hearth steel costs respectively 17s. and 22s. per ton, and about 25 per cent. of coal is required. An electric open-hearth furnace would require per ton of steel about 0·15 horse-power per year instead of about 3s. for coal. After deducting the expenditure, for electrodes, of 1s. 6d. per ton, there only remains 10s. as the admissible cost of one horse-power per year, which is not attainable. It appears, therefore, that the electric furnace cannot compete with the Bessemer or open-hearth processes. In the manufacture of crucible cast steel the conditions are much more favourable for the electric furnace. Crucible cast steel requires 100 to 150 per cent. fuel, and from eight to twelve crucibles at 5s. each per ton of steel. General furnace repairs and wages in crucible steel manufacture cost the same as in electric smelting, and the cost of electrodes and energy may amount to 15s. shillings per ton of steel, with 40s. extra for crucibles. This proves, in the author's opinion, that electric manufacture of steel does not only depend on cheap water-power, but can with advantage be added to existing steel works where a further more important advantage in the use of fluid raw material exists.

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* *Cassier's Magazine*, vol. xxx. pp. 23–36, with nine illustrations.

† *Canadian Engineer*, May 1906.

‡ *Revue Universelle des Mines*, vol. xv. pp. 206–222.

§ *Revue Mineralurgique*, vol. iv. pp. 84–85.

‖ *Canadian Mining Review*, vol. xxvi. pp. 174–178.

¶ *Zeitschrift für Elektrochemie*, vol. xii. p. 231.

R. S. Hutton * deals with the electric furnace and its application to the metallurgy of iron and steel. He gives the cost of production by water-power, per electrical horse-power year, as charged to large consumers, as follows: At Niagara, £3, 11s. to £4, 3s.; at Sault Ste. Marie, £2, 1s. 6d; Kanawha Falls, Virginia, £2; Sweden, 13s. to £1, 10s; Meran (Austria), £2, 7s. 6d.; Savoy (Bellegarde), £2, 4s.; Savoy (Chedde), 18s. 4d.; Norway, 12s. to £1, 10s. Many inconveniences, however, attach to water-power for generating electrical energy. As to steam plants, very little has been made public as to the costs in the few large works that run continuously at full load for long periods. He gives, however, a table of works costs per unit, including Sheffield (Neepsend), 0·2092d.; Newcastle (Carville), 0·12123d.; Watson's Works (Linwood), 0·205d. In addition, he estimates 0·063d. per unit in each case for capital costs. The furnaces in use for the manufacture of ferro-alloys range in power from 200 horse-power to 2000 horse-power. There are large plants in the United States and Switzerland, but the most important plants are in Savoy and Isére, in the South of France. At Grenoble there are five furnaces of 1200 horse-power, and four of 2000 horse-power, used for the manufacture of ferro-silicon, ferro-chromium, silico-spiegels of varying composition, and manganese-silicon. The output has been about 8000 tons per year. At Giraud's works the furnaces aggregate 18,000 horse-power, and are to be increased to 40,000 horse-power. 5000 tons of ferro-silicon (50 per cent.); 1000 tons of ferro-silicon (30 per cent.); 2000 tons of ferro-chromium; 800 to 900 tons of ferro-tungsten; 50 tons of ferro-molybdenum, and about 10 tons of ferro-vanadium have been produced during the year. The

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* Paper read before the Sheffield Society of Engineers and Metallurgists, October 1, 1906; *Engineering*, December 7, 1906; *Iron and Coal Trades Review*, vol. lxxiii. p. 1264.

power expenditure per metric ton in the manufacture of electrically produced steel for various types of furnace are given as follows: Kjellin furnace, 0·10 to 0·16 horse-power year; Héroult, 0·11 to 0·17; Stassano, 0·186 to 0·219; and Keller, 0·125.

Albert Neuburger * deals with improvements in existing electric furnaces, and describes the new Gin furnace. The Gin furnace refines pig iron, like the Kjellin furnace, without the use of carbon electrodes. The composition of a furnace charge is also given.

Drawings of the Gin electric steel furnace are also given by F. C. Perkins.†

L. Katona ‡ gives a detailed account of the Héroult method of electric iron-smelting. R. H. Wolff § combats the suggestion that the Héroult process is intended to compete with the blast-furnace, and enumerates the conditions which it is intended to meet.

Albert Hiorth, || in addition to a description of the Leleux, Héroult, Harmet, Kjellin, and Gin furnaces, gives figures concerning the cost of working and economy of a new type of electric furnace of his own invention. Illustrations of the Hiorth continuous induction furnace for electric smelting have also been published ¶ elsewhere.

J. B. C. Kershaw ** describes the Keller furnace and process of smelting.

The Kjellin process is described by W. von Rüdiger.††

The pioneer electric steel furnace in the United States is described and illustrated.‡‡ It has been installed at the Tacony Works of Henry Disston & Sons, near Philadelphia, Pennsylvania. The induction type of furnace built by the Induction Furnace Company, Newark, New Jersey, under the patents of E. A. Colley, has been adopted. The furnace is practically an electric transformer or induction coil, in which the metal to be melted is arranged in a closed ring-form in the annular opening of the crucible; the crucible encircles the central member of a laminated iron core which extends across the top, two sides and bottom of the crucible constituting a

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* *Glasers Annalen für Gewerbe und Bauwesen*, vol. lviii. p. 103.

† *Mining World*, vol. xxv. p. 494.

‡ *Banyaszati es Kohaszati Lapok*, vol. xxxix. pp. 285–294.

§ *Iron Age*, vol. lxxvii. pp. 1990–1991.

|| *Berg- und Hüttenmännische Rundschau*, 1906, p. 272.

¶ *Teknisk Ugeblad*, vol. liii. p. 252; *Chemiker Zeitung Repertorium*, vol. xxx. p. 267.

** *Iron Trade Review*, August 30, 1906, pp. 17–20.

†† *Giesserei Zeitung*, vol. iii. p. 385.

‡‡ *Iron Age*, vol. lxxvii. pp. 1811–1813.

closed magnetic circuit. This iron core is converted into a powerful magnet of alternating polarity by passing an alternating current of low amperage through a conductor surrounding its central member. With each alteration of current in the latter, or primary conductor, a current of electricity is induced in the metal, placed in the annular cavity of the crucible, of sufficient amperage to quickly raise it to the melting point. Complete control of the temperature can be obtained by means of a rheostat in the primary circuit. The steel is melted by the heat developed within its own mass by the passage of the induced current. At the Disston Works the usual charges have been 150 lbs., the cast ingot weighing 90 to 100 lbs., leaving 50 to 60 lbs. of molten metal in the furnace after teeming, to which fresh metal is added for the succeeding charge. The melting down of the charge takes about twenty minutes, and another forty minutes are required to work it. A heat thus averages a little over one hour. The metal obtained is very dense and fine grained, and absolute control is had over its quality by means of the additions made. The construction of larger furnaces is contemplated, with a view to ascertaining the size of unit best adapted to the requirements of the firm.

At the Tacony Works, near Philadelphia, the electric furnace is of the Kjellin type.* The primary current has a tension of 220 volts, which is transformed down to 8 volts. The charges, consisting of Swedish iron and scrap, average 154 lbs.

A description and illustrations have appeared † of a 1000-ampère Moissan experimental electric furnace, built by Marryat and Place, London.

E. Stassano ‡ describes the production of iron in the electric furnace.

The Niagara Falls electro-chemical and metallurgical industries are described by F. C. Perkins.§

The smelting of Canadian iron ores by electricity is dealt with by F. Peters.||

The practical trials carried out under Government auspices as the outcome of the Canadian Commission on Electric Smelting have attracted considerable attention. An abstract of E. Haanel's pre-

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* *Bihang till Jernkontorets Annaler*, 1906, pp. 339-341.

† *Engineering*, vol. lxxxi. p. 381.

‡ *L'Electricien*, vol. xxxii. pp. 65, 82.

§ *Mining World*, vol. xxiv. pp. 661, 691-692, 721-722.

|| *Glückauf*, vol. xlii. pp. 1015-1017.

liminary report on the experiments at Sault Ste. Marie has been published,* with comments by P. Thompson.†

The official preliminary report of the Dominion Government on the experiments made at Sault Ste. Marie in the smelting of Canadian iron ores by the electro-thermal process has been published.‡

E. G. Odelstjerna § summarises the results obtained at Sault Ste. Marie, Canada, in smelting Canadian iron ore in the Héroult electric furnace. Analysis and details of cost are given.

F. Cirkel || deals with the production of pig iron by means of the electric furnace, quoting from the report of the Canadian Commission on the subject. The satisfactory nature of this report has led the Canadian Government to institute a systematic inquiry into the large as yet unworked iron ore resources of the Provinces of Quebec, Ontario, and Nova Scotia, and as to the water-power available in the vicinity of these ore deposits.

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* *Electrochemical and Metallurgical Industry*, vol. iv. pp. 265–268.

† *Engineering and Mining Journal*, vol. lxxxii. pp. 24-25.

‡ *Canadian Engineer*, June 1906; *Bihang till Jernkontorets Annaler*, 1906, pp. 378–395.

§ *Teknisk Tidskrift, Kemi och Bergsvetenskap*, vol. xxxvi. pp. 93-102.

|| *Stahl und Eisen*, vol. xxvi. pp. 868–871, with two illustrations.

FORGE AND MILL MACHINERY.

Forging Presses.—An illustrated description has appeared [*] of a 3000-ton press recently built by Davy Brothers, Limited.

Drawings have been published of a 1200-ton hydraulic press, a 6-ton steam-hammer, and a rolling-mill for the Japanese railway tire works at Yawata.[†]

Steam Turbines.—A description is given [‡] of the Rateau steam turbine plant installations at the works of the Steel Company of Scotland, Hallside, and at Hucknall Torkyard colliery, near Nottingham, respectively. At both works the power is derived from waste steam discharged from other engines. The amount of steam available at the first-named works was estimated at 41,000 pounds per hour. An accumulator has been installed, together with a 700 brake horse-power turbine with eleven wheels. This turbine develops full power at 1500 revolutions per minute, and is coupled to a Siemens direct-current 230 volt generator. The colliery plant at Hucknall Torkyard is smaller and consists of an accumulator using scrap rails, a turbine of 175 brake horse-power running at 3000 revolutions per minute, and a three-phase generator, 50 cycles per second, 500 volts

The Allis-Chalmers steam turbine is described and illustrated,[§] with special reference to the details of the blades, and their mode of setting.

The first application of the Rateau system for the utilisation of exhaust steam for low pressure turbines in America is recorded.[‖] An installation is being put down at the works of the International Harvester Company, Irondale, South Chicago.

[*] *Engineer*, vol. ci. pp. 428–430, with six illustrations.

[†] *Engineering*, vol. lxxxii. pp. 520–523, with thirteen illustrations.

[‡] *Ibid.*, vol. lxxxi. pp. 848–849, with seventeen illustrations.

[§] *Iron Age*, vol. lxxvi. pp. 1601-1603.

[‖] *Ibid.*, vol. lxxviii. p. 139.

Electricity in Rolling-Mills.—V. Graubner* discusses the use of electricity for driving rolling-mills.

B. Wiley † describes a rolling-mill equipped entirely with electric motors.

F. Janssen ‡ details some experience in practice with electric power as supplied to rolling-mills.

H. Koch § deals at considerable length with the use now made of electricity in smelting works. Its application for power purposes is specially dealt with. For reversing rolling-mills there are great difficulties so far as electric power is concerned. Colossal power comes into action—it may be up to 6000 horse-power or more—and this has to be started and controlled. Still the Ilgner system enables this to be done. This method has up to now been chiefly used for shaft-winding purposes.

E. Hofmann ‖ gives some results which have been obtained at the Peine Works with two three-high rolling-mills for which electricity has been employed as the motive power. The mills themselves are also described. Electro-motors have proved most satisfactory.

J. Weil ¶ gives a short comparison of the different electric driving plants in ironworks, and remarks that a steady increase in the number of applications is to be noticed since the Düsseldorf Exhibition. The principal reason is the utilisation of blast-furnace gases in large gas-engines to produce electrical energy economically. A gas-engine which is coupled to four continuous-current compound dynamos of 240 kilowatts at 150 revolutions per minute, and also a four-cylinder gas-engine coupled to a dynamo of 450 kilowatts are mentioned. A gas-cleaning plant is also worthy of mention. It consists of three cylinders in which wooden gratings are placed, and these are continually sprinkled with water from above.

Rolling-Mills.—W. H. A. Robertson ** discusses the design of rolling-mills with special reference to the wearing surfaces, methods of lubrication, and fitting and machining of important parts.

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* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 239–241 and 264–266, with four illustrations.

† *Electrical Journal*, vol. iii. pp. 456–463.

‡ *Stahl und Eisen*, vol. xxvi. pp. 852–854.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 417–424, 429–436, 442–447, 453–457, 467–470, and 482–486, with forty-one illustrations.

‖ *Stahl und Eisen*, vol. xxvi. pp. 654–657.

¶ *Zentralblatt der Hütten- und Walswerke*, 1906, No. 20.

** *Iron and Coal Trades Review*, vol. lxxii. p. 1322.

P. Fröhlich * deals with rolling processes, considering them from a mechanical and mathematical standpoint.

J. Lormier † traces the progress made in rolling-mill practice, taking certain periods as representing the various stages which have been reached, from the earliest times to the present day. During the last few years great changes have taken place, while present practice largely favours the increased application of electrical machinery to mill operations. He describes the principal types of machines now in use, such as shears, electric chargers for reheating furnaces, and rail straightening and dressing machines.

A. Bartholme ‡ gives the conditions on which the production of a rolling-mill depends: (1) The revolutions per minute; (2) the distribution of the passes; (3) the amount of material rolled out each pass; and (4) the length rolled.

B. H. Reddy § describes the design of billet and bar passes.

A. L. de Leeuw ‖ discusses the design of bending rolls.

W. Tafel ¶ observes that every manufacturer making round iron finds extreme difficulty in keeping its dimensions true. If, for instance, it is required that the diameter shall be between 0·61 inch and 0·63 inch it is not every works that can insure the variation in diameter being only between these limits, and no works will do so without difficulty. The ordinary methods of rolling in use are first described, and the author then describes another for which he has obtained German and other patents. In this an oval rod is made to pass through two sets of rolls mounted tandem, which impart to it the necessary round form, the bar being unable to twist during its passage through these rolls.

The cold rolling-mills of the Walzmaschinen-fabrik, Düsseldorf, are described** and illustrated. The smallest mill has rolls 4 inches in diameter by 5 inches wide, and the largest 8 inches in diameter by 7 inches wide.

H. Crowe †† describes German rolling-mill practice from observations made on the occasion of a recent visit to the chief industrial centres. For cogging, mills of large diameter are preferred, and at most works reheating has been abolished in favour of rolling off.

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* *Stahl und Eisen*, vol. xxvi. pp. 922–925, with three illustrations.

† *Bulletin Technologique*, 1906, pp. 651–696.

‡ *Zeitschrift des Vereines deutscher Ingenieure*, vol. l. pp. 1285–1286.

§ *Machinery* (New York), vol. xii. pp. 451–452.

‖ *American Machinist*, vol. xxix. pp. 644–647.

¶ *Stahl und Eisen*, vol. xxvi. pp. 1240–1247, with eight illustrations.

** *Iron Age*, vol. lxxvii. pp. 1893–1894.

†† *Engineering*, vol. lxxxi. p. 774.

More compound three-crank engines are being built, and existing three-crank high-pressure engines are being converted into compound engines, while mills driven by gas-engines are becoming increasingly common.

American rolling-mill practice is described by G. Rivière.*

The new mills of the Youngstown Sheet and Tube Company, East Youngstown, Ohio, are described † and illustrated. The pit-furnace building is 80 feet wide and 280 feet long, and is furnished with a Morgan electric stripper of 100 tons capacity. There are four four-hole pit furnaces, with hydraulically operated covers. The furnaces are fired by gas from eight large Duff producers, housed in an adjoining building. The blooming-mill is 45 feet wide and 360 feet long, and is of the combination type. It can roll slabs up to 30 inches wide, the diameter of the rolls being 33 inches, and the length, from neck to neck, 80 inches. The mill has been built from the designs of J. Kennedy, and the engines are of the twin reversing type. The main blooming tables are 40 feet long, and the extension tables 120 feet long. The continuous billet and bar mills contain ten and eight pairs of 18-inch rolls respectively, and have flying shears of the Edwards type. There is also a 42-inch universal plate-mill, in which plates can be rolled 42 inches wide with the vertical rolls in, and 66 inches wide by removing the vertical rolls. The power plant consists of two 400-kilowatt Westinghouse generators, and one 800-kilowatt Bullock generator, all of which are driven by William Tod cross compound engines, while the boiler plant consists of sixteen Sterling boilers of 500 horse-power each.

An illustrated description has appeared ‡ of the new structural steel mill of the Jones and Laughlin Steel Company, Pittsburg, which, it is claimed, is the largest rolling-mill in the world. It occupies a space 490 feet long and 320 feet wide, and consists of one large mill building containing the furnaces, the roughing and finishing mills, roll racks, and part of the hot bed, a shear building, and a stock building. There are thirteen cranes, all driven electrically. The furnace charger consists of one large hydraulic cylinder at the back of each furnace, with the front end of the ram carried by supporting beams acting as guides to keep it in line. There are three furnaces, the inside dimensions of each furnace being 17 feet between the walls, enabling the operator to run one or two rows of billets.

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* *Mémoires de la Société des Ingénieurs Civils*, 1906, No. I. pp. 383–396.

† *Iron Age*, vol. lxxviii. pp. 259–267.

‡ *Iron Trade Review*, April 26, 1906, pp. 16–24; *Iron Age*, vol. lxxviii. pp. 9–14.

Provision is made for a fourth furnace, and natural gas is used as fuel. The design of the mill has been exceptionally heavy with a view to reducing the repair cost. The mill is a 26-inch one, with rolls 66 inches long and, when new, 28 inches in diameter, it being the intention to work them down to a 24-inch diameter. The mill will roll angles 4 inches by 4 inches to 8 inches by 8 inches inclusive. The roughing and finishing trains are driven by engines of the Corliss type, the largest engine having a 42-inch high pressure cylinder, 74-inch low pressure cylinder, and 54-inch stroke. The fly-wheel is 18 feet in diameter and weighs 175,000 lbs.

The recent extensions carried out at the works of the Illinois Steel Company, South Chicago, are described * and illustrated. They include an additional blast-furnace and seven open-hearth furnaces, new soaking pits for the 40-inch blooming-mill, and a third re-heating furnace in the structural mill. A 30-inch universal plate-mill and a light rail-mill are now under construction. Both mills will be electrically driven, no steam or hydraulic power being used, and compressed air will be employed instead of water to clean the scale from the slabs as they are rolled. The plate-mill will roll plates 6 inches to 30 inches wide, and up to a length of 80 feet; it will have a capacity of 7500 tons a month. The mill has rolls 24 inches in diameter and 67 inches long, and is so constructed that the vertical rolls can be brought much nearer to the horizontal rolls than is generally the case, while the vertical rolls can also be removed vertically and without disturbing their driving shaft. A 30-ton travelling crane is provided for handling rolls and changing machinery. The building is 83 feet by 700 feet, and has a storage yard 83 feet by 300 feet between it and the slabbing-mill. This mill will be the first electrically driven reversing-mill in the United States, and the rolls will be driven by direct-current motors capable of a torque of 345,000 lbs. at a radius of 1 foot. This, if exerted at maximum speed, would require the motors to develop about 10,000 horse-power. The two mill motors are mounted on the same shaft in order to secure small diameters and low fly-wheel effects for the revolving elements. The maximum speed is 150 revolutions per minute, and the motors are expected to reverse from full speed in one direction to full speed in the opposite direction in three seconds; this means a rate of acceleration of 100 revolutions per minute. The new rail-mill—which is for light sections only—is 60 feet by 426 feet, including the hot beds, while the finishing end is 45 feet by 360 feet, and the motor room 33 feet by 160

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* *Iron Trade Review*, July 5, 1906, pp. 22-26.

feet. There are three stands for a 24-inch mill, two being in line for roughing and finishing, with an intermediate stand of leading rolls, 100 feet tandem. Each train will be driven by a Westinghouse alternating-current motor of 1800 horse-power directly connected to the trains and running at 120 revolutions when re-rolling old rails to smaller sizes, or 80 revolutions when handling billets and blooms. Six Duff gas-producers supply gas for the two continuous heating furnaces, which are of the regenerative type, one 17 feet by 40 feet, and the other 21½ feet by 27 feet.

Illustrations are published * of machines for doubling sheets for thinner rolling. Those referred to are of German design, one being arranged for electric driving.

A description is given † of a hot system rolling-mill invented by W. Kent of Covington, Kentucky, and designed to obviate the necessity of doubling in rolling sheets.

An illustrated description has appeared ‡ of the recent extensions to the rolling plant of the Bethlehem Steel Company's works, at South Bethlehem. The extensions, which will be known as the Sancon plant, comprise the installation of additional open-hearth furnaces, mills for structural sections, and rail-mills. The material produced will be special wide flange rolled beams, rolled girders and column shapes of H-section, open-hearth and nickel-steel rails, open-hearth billets, I-beams, channels, angles, and other standard structural shapes. The new plant will involve an expenditure of over £2,500,000. To furnish the necessary material for the new mills an additional blast-furnace of 600 tons capacity is being erected, and will shortly be completed. Ten 50-ton open-hearth basic furnaces are being built. There will be a 46-inch blooming-mill for the Grey patent beam-mills. This blooming-mill will be driven by a 40 and 66 by 54 inch twin tandem reversing engine with geared connection. A modified Wellman-Kennedy manipulator will be used. There are two Grey mills; a 48-inch intermediate mill and a 48-inch finishing mill, the blooms travelling from one to the other, after blooming, and without re-heating. The two Grey mills are universal mills of identical construction, and will be driven by engines similar to those of the blooming-mill, but directly connected. The structural mill will be served by a 40-inch blooming-mill, and is a 28-inch mill of the three-high type, with three stands of rolls, arranged to be used

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* *Stahl und Eisen*, vol. xxvi. pp. 735–736, with four illustrations.

† *Iron Age*, vol. lxxii. p. 1679.

‡ *Ibid.*, vol. lxxviii. pp. 1142–1146, with eight illustrations.

as a two-high mill if desired. It will roll standard beams and channels up to 15 inches deep and angles from 3 to 8 inches, and will have a capacity of 400 tons per day. There will also be a 28-inch rail-mill, arranged to roll shapes if desired. The capacity of the rail-mill will be 1000 tons of rails per day. The power equipment of the new plant will be furnished by Stirling water-tube boilers arranged in batteries of 1000 horse-power each, and aggregating 18,000 horse-power. The most interesting feature of the new works will, however, be the Grey universal mill for rolling beams. The structural details of this mill, and the respects in which it differs from other Grey mills elsewhere, and particularly from the mill at Differdingen, are fully described. Girders can be rolled in this new mill up to 30 inches deep, weighing 200 pounds per foot.

The new finishing-mill of the Atlanta Rolling-mill and Tinplate Company is figured and described.* The works are situated on the outskirts of Atlanta City. The new mill is intended to produce both sheets and tinplates, but its output will at present consist of light sheets and black plates. There are four hot mills, two of which have 36-inch rolls, while the other two are furnished with 32-inch rolls, both arranged parallel to the length of the main building. There are also two cold mills, which are arranged tandem and are at right angles to the hot mills. Provision has also been made for the installation of two additional 40-inch hot mills. They are all of the standard type, having steel spindles, boxes, housings and rolls, and have been built by the United Engineering and Foundry Company of Pittsburg. The hot mills are driven through a 14-feet steel gear weighing 40 tons, by a 32 by 60 inch Corliss engine, equipped with an 18-feet flywheel weighing 55 tons. The cold rolls are geared to a smaller Corliss engine by means of three straight tooth gears. There are two 44-inch and two 38-inch doubling shears situated in front of the hot rolls and between the latter and the heating furnaces, driven by Westinghouse motors. The sheet furnaces are heated by producer-gas, and are 7 feet by 8 feet in the clear, while the pair furnaces are 6 feet by 8 feet. Provision has been made for installing two additional furnaces, but the present gas-producer plant, being sufficient for future requirements, will not, in this case, need to be enlarged or supplemented. A number of shears have been provided, together with a complete installation of charging plant. Steam is supplied by eight 150 horse-power tubular boilers equipped with Roney stokers.

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* *Iron Age*, vol. lxxviii., pp. 725, 726, with five illustrations.

PRODUCTION OF STEEL.

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I.—*THE CARBURISATION OF MALLEABLE IRON.*

The Cementation Process.—R. Bruch * gives the results of experiments relating to the cementation of wrought iron by cementing agents in the form of gas or vapour. The agents employed were illuminating gas, petroleum vapour, acetylene, and carbonic oxide.

Native Steel from Ceylon.—Steel made near Balangoda by the primitive native method is shown by W. R. Dunstan † to have the following composition :—

Iron.	Manganese.	Silicon.	Sulphur.	Phosphorus.	Combined Carbon.
97·77	0·07	0·07	0·07	0·02	1·97

These results do not indicate that the local belief that it is of better quality than English crucible steel is well founded.

Direct Steel Production.—D. H. Ross ‡ describes the Heskett-Moore process of producing steel direct from the ore.

The various methods for the manufacture of steel are briefly considered by W. Schmidhammer, § who precedes his description of them by a statement as to what is to be understood by the term steel. He understands by this expression all those solutions of metals and non-metals in iron which are or can be manufactured for particular technical uses, and possess distinct properties differing from those of wrought iron.

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* *Metallurgie*, vol. iii. pp. 123–128.

† *Colonial Reports, Miscellaneous*, No. 37 [Cd. 3190], 1906, p. 33.

‡ *Iron Trade Review*, July 12, 1906, p. 19.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 489–491, and 501–504.

II.—*THE OPEN-HEARTH PROCESS.*

Open-Hearth Furnace Practice.—J. Ward * gives a number of practical directions for the successful working of a small open-hearth plant. After noting the precautions to be observed in drying the furnace and putting the gas in, he deals with reversing, the lining and repair of the bottom, the working of the wash-out charge, and the general charging of the furnace. He notes a precaution to be adopted in sample taking. The spoon should be heated, dipped into the metal, raised to the surface, part of the steel poured off, and the remainder covered with slag, which should be skimmed into the spoon.

German practice is described by H. Crowe.† The furnaces are mostly below 30 tons capacity, and are nearly all worked with a large percentage of scrap, in a shallow bath. The general practice is to cast in pits, even in the newest works, such as Rombach. He notes the improvements which have been effected in the working of the Bertrand-Thiel process, as many as thirty-two finished heats being obtained in an 18-ton furnace per week, making nearly 600 tons, with a yield of 104 per cent. on the metal charged.

W. M. Carr ‡ discusses the manufacture of open-hearth steel. He deals with American practice in the construction of the furnace, taking an average capacity of 20 tons. Tilting furnaces offer more advantages in the manufacture of castings than stationary furnaces, as the metal can be completely drained off, and the bottom is not subjected to as much scorification from pools of residual metal. Wherever possible, the doors, door frames, and furnace fronts should be water-cooled. The depth of the hearth should be regarded as a matter of importance. The fuel efficiency will depend largely on the length of the furnace and on the proper construction of the regenerator chambers. Observations on the normal working of the waste gases have shown that the heat absorption and radiation by the chequer-work may easily account for 1000° C. In the best designed furnaces, the chambers are placed at the ends, and extend at right angles to them under the charging floor. He then discusses the relative treatment for acid and basic linings. In the case of the latter he points out that while a magnesite hearth is more costly, it gives the best results in practice. The selection of fuel is then considered, and the arrangements necessary for the employment of liquid fuel are detailed. In European practice, producer-gas is usually employed. The process of melting down and the subsequent working of the charge, together with the chemical reactions involved, are then discussed, and a diagram given showing the variations in composition of a normal acid open-hearth heat. The selection of materials and the method of working to given specifications are then described, and the precautions for manipulating the heat in order to secure uniformity in the product are detailed at length.

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* *Birmingham University Engineering Journal*, vol. v. pp. 43–47.

† *Engineering*, vol. lxxxi. p. 774.

‡ *Iron Trade Review*, February 8, 1906, pp. 24–26; March 8, 1906, pp. 18–21; and April 12, 1906, pp. 20–22.

E. Reinke * gives further particulars regarding the use of liquid fuel in regenerative furnaces.

K. Brisker † discusses the proposals of G. Reitboeck further to develop the use of the mixer. Experiments have already shown that it may be turned from a simple mixing appliance to one in which, by the addition of some ore and extra heating, the metal is subjected to a preliminary fining process. Instead of the ore, Reitboeck proposes to add a completely decarburised and over-oxidised iron, this charge being made in its superheated molten condition. In addition to the increase in temperature of the mixer's charge that then results by simple admixture there is a considerable reaction, which adds greatly to the temperature of the metal. This increase can best be utilised by reducing ore added to the bath. This ore addition may be considerably greater than that which would be possible in the ordinary way. The resulting mixer product contains about 2·5 per cent. of carbon, and is finished in the usual way. Details are given as to a trial of this method on a practical scale. Its use is accompanied by a considerable saving of time in the working of an open-hearth charge.

Chemical Action in the Acid Open-Hearth Furnace.—Deslandes ‡ sums up the results of his studies on the different elements which take part in the reactions in the basic open-hearth steel furnace. He divides the cycle of operations into two main series, those which occur during fusion and those which occur after fusion. The latter series is the only one with which he deals specifically. He regards the reactions as functions of the coefficients of solubility (1) of the constituents of the bath in the slag, (2) of the constituents of the slag in the bath. These coefficients depend upon the temperature and the chemical composition of the two main solvents, the slag and the metal. Inasmuch as in the open-hearth furnace the combustion of the gases leads to a gradual rise of temperature, and thus alters the composition both of the slag and of the bath from time to time, there can never be a condition of stable equilibrium between the different elements. Basing his calculations on baths and slags of conventional composition, he gives a series of diagrams showing the solubility of the principal elements concerned in the bath and in the slag respectively, and discusses separately the behaviour and the special functions of the silicon, manganese, sulphur, phosphorus, and nickel, when the latter is present.

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* *Glückauf*, vol. xlii. pp. 1377–1384.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 319–321.

‡ *Revue de Métallurgie*, 1906, pp. 321–330.

R. Mather* deals with the chemical reactions occurring in the open-hearth process, both acid and basic, and their practical application in working the charge.

Talbot Continuous Process.—The first Talbot furnace to be erected in the Continent of Europe was recently put into operation at the steelworks at Senelle, France. The hearth is 50 feet 10 inches in length by 23 feet in maximum width. The furnace with its charge weighs about 600 tons, the charge itself weighing 160 tons. Two hydraulic lifting jacks, each of 650 tons power, move the furnace. The iron is taken from a 175-ton mixer. The charge consists of 50 tons of pig iron. It is anticipated that three 50-ton charges will be worked off daily, instead of the two or two and a half as at first. About 20 to 25 per cent. of Swedish iron ore is added. The furnace is provided with four producers, three of which are always in operation together.†

Bertrand-Thiel Process.—The most recent developments of the Bertrand-Thiel process are described.‡ The methods practised at Kladno in Bohemia and at Donawitz are given in detail, and the results obtained are discussed. Emphasis is laid on the necessity of accurately adjusting the quantities of limestone and of ore employed in the first stage of the operations. The percentage of phosphorus in the pig usually varies but little. The silicon, however, may alter considerably from one cast to another. It is, therefore, necessary to ascertain by using sufficient ore and limestone, how much is necessary to eliminate the phosphorus and silicon. The ores used should be rich in iron, and Swedish ore is suitable for the purpose. Lime is likewise found better in practice than limestone, as the time saved in calcining the limestone shortens the process. If the fusion of the mixture of ore and lime is carried too far, the reactions caused on the addition of the pig iron become too violent, and occasion losses by the cutting action on the lining of the furnace, and sometimes by masses of metal being projected through the openings. The ore and lime should be charged from twenty to twenty-five minutes previously to the pig iron. The appearance of the slag is a guide to determining the exact period at which it should be separated from the bath. It should be rather sluggish and should liberate bubbles of carbon dioxide, but before its removal the second stage of the operation should be prepared for in the secondary furnace, by heating up a supply of lime, or limestone and ore. If scrap be used, it is usually added in the proportion of 10 to 20 per cent. of the weight of pig iron. Tables are given showing the working down of charges at the furnaces at Kladno.

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* Paper read before the Sheffield University Chemical Society; *Engineering Review*, vol. xiv. pp. 375–376.

† *Moniteur des Intérêts Matériels*, vol. lvi. pp. 1847–1848.

‡ *Génie Civil*, vol. xlviii. pp. 4–6.

Schwartz Steel Process.—A process of manufacturing steel in a Schwartz furnace, supplemented by cupola-melted metal, is described.* About a ton of low phosphorus iron and steel scrap are melted in a cupola, while about 7 cwt. of scrap and a ton of similar pig iron are heated in the furnace. The cupola charge is added to the furnace contents, when, owing to the large proportion of scrap, the charge can be worked down in two and a half hours. Liquid fuel is used, and a temperature of 4000° F. can be obtained, the entire process occupying about four hours. Eighty gallons of oil are consumed per ton of steel made. The furnace can also be used for the production of malleable iron.

Comparison of Open-Hearth Processes.—A. Bosser † institutes a critical comparison between existing modifications of open-hearth steel practice, such as the scrap and ore processes, the Bertrand-Thiel process, and the Talbot process. After defining what constitutes a scrap process, and the conditions under which such a process becomes economically remunerative, he points out that the employment of such processes is, in practice, confined to operations in a basic-lined furnace, except for the production of small quantities of special steels, or of small steel castings. A basic lining accelerates the elimination of carbon and silicon, and hence increases the productive capacity of the furnace by reducing the time required in working down the charges. He considers that the attempts which have been made to increase the proportions of ore charged, at the expense of that of the scrap, are of very little actual benefit. The larger proportion of foreign constituents, such as carbon, silicon, phosphorus, and manganese, introduced by these means, occasion reduction of make by occupying a longer time in working, while they entail higher fuel consumption and increased expenses in furnace repairs, owing to the destructive action of the slags on the linings, which reduces the life of the furnace. He gives a number of typical charges, together with analyses of the materials employed and of the resulting steel. The attempts to shorten the length of the operations by introducing liquid pig iron with scrap charges, he considers equally unsatisfactory. The higher temperature of the liquid pig iron certainly hastens the oxidation of the silicon, manganese, phosphorus, and carbon, but this advantage is counterbalanced by the fact that, with a liquid bath, this oxidation can only take place at the surface, whereas when the solid pig iron melts it does so drop by drop, and exposes a greater surface to oxidation during the process of melting down. The length of the operation of working down the charge is about the same in either case. Charging liquid pig iron and ore in furnaces of small capacity has yielded no better results. The various chemical reactions and their heat equivalents are discussed in detail in confirmation of the foregoing views. He considers the results as due to the fact that the heat stored up in the liquid pig iron has not been taken full advantage of. The reserve heat of the liquid pig iron charged should suffice to bring about the reduction of the ores and mill scales which are added to the charge. Instances of the present practice at Donawitz and at Jouriefka, where these so-called direct ore processes are in operation, are given. In both these works highly satisfactory results have been obtained by attention to these points. At Donawitz the furnaces, four in number, have a capacity of 25 to 30 tons, and are regularly producing four heats daily, the yield from the ore employed amounting from 80 to 85 per cent. The duplex process, in which operations are carried on in a Bessemer converter, and subsequently in an open-hearth furnace, is also described. In this case, likewise, the substitution of liquid pig has proved highly satisfactory. He deduces from these examples the following advantages which should arise from the use of liquid pig iron when employed in the most favourable circumstances: (1) The heat stored in the pig iron serves to reduce the ore and mill scale additions; (2) the expense of casting pig iron at the furnace, the subsequent handling, and the costly charging into the furnace are obviated; (3) the working of the charges takes less time, and the temperature of the furnaces is more easily maintained, owing to which there is a saving in fuel and labour costs; (4) the heat imparted to the furnace reduces the fuel consumption in direct proportion to the increased efficiency of the furnace; (5) the steel produced has better welding qualities; (6) the steelworks no longer depend upon the supply or price of scrap, as the proportion of pig iron charged can always be depended upon to supply any deficiency; (7) the proximity of the steel furnaces to the blast-furnaces allows of the direct use of the waste gases of the latter to appliances in the former. He points out that in such an installation a heated metal mixer is a necessity, in order to regulate the pig iron supply.

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* *Iron Age*, vol. lxxvii. pp. 1389–1390.

† *Revue Universelle des Mines*, vol. xiii. pp. 1–30.

The Bertrand-Thiel process seeks to accelerate the working of the charge by dividing it into two portions and working each down in a separate furnace, and to increase the yield by making ore additions. The practice followed at Kladno is described, but it is pointed out that despite the satisfactory nature of the results obtained, the process has not been very widely adopted. It has only been since its employment at the Hoesch Steelworks at Dortmund that it has succeeded in arousing much attention. The plant and the sequence of operations as carried out at these works are then described. It is pointed out that the plant was originally designed for the scrap process, and is not particularly well adapted for the Bertrand-Thiel process. The furnaces are too small. Nevertheless, it would appear that nine or ten heats can be obtained per day, which is a remarkable result. The process requires a high temperature throughout, which doubtless favours the working of the charges and the reduction of the ore additions. The process is independent of the quality of the pig, but with very high percentages of phosphorus difficulties are experienced with the slags. At the Hoesch Works the pig iron contains 1·8 per cent. of phosphorus, and it may be assumed that with lower phosphorus pig iron the number of heats could be increased. The results seem to show that the Bertrand-Thiel process is the most economical which can be adopted in circumstances where an acid open-hearth plant is situated in close proximity to the blast-furnaces, and can reap the advantages which accrue from such a disposition. The author then discusses the Talbot process, the plant and sequence of operations being described in detail. The process of starting the Talbot furnace resembles that employed in the scrap process. As the production per heat only represents a quarter of the whole contents of the furnace, it would seem unreasonable to attempt to re-carburise in the furnace itself. This could best be effected in the ladle by additions of anthracite and of ferro-manganese previously heated. The proportion of ore which can be added to the bath will depend upon the composition of the pig iron used. It could be increased by calcining and briquetting previous to its being added. If the addition of ore could be increased from 20 to 40 per cent., the yield of metal would rise to 115 per cent., and the cost of calcining would be covered by the increased yield. The yield will also depend on the size of the furnace. From this point of view the best results appear to be obtained with furnaces of 150 to 200 tons, from which one-quarter or one-third of the charge is periodically tapped. A high percentage of phosphorus delays the working, for a reduction of the phosphorus to 0·09 per cent. entails working the carbon down to 0·07 per cent. The crux of the process would appear to be in the re-carburisation of the steel, which should be carried out in the ladle. This renders it difficult to secure homogeneity. He contrasts the relative advantages and disadvantages of re-carburising in the furnace and in the ladle, and concludes that the Talbot process is not applicable to the manufacture of steel of high class, containing 0·10 per cent. of carbon or less, and required to fulfil definite physical and chemical requirements. It is more suitable for steel of a somewhat lower grade. Despite the increased yield and the reduction in working costs and in fuel consumption, the process has not been widely adopted, probably because it is difficult to produce by its means a steel which can meet the stringent requirements of Continental railway engineers, and also because the initial cost of installation is very high.

French Open-Hearth Furnace.—G. Hofer * describes a furnace installed by Defays at St. Monceau St. Fiacre, for producing open-hearth steel of good quality.

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* *Giesserei Zeitung*, vol. iii. p. 353.

American Open-Hearth Furnaces.—G. Rivière[*] deals with American practice at open-hearth steelworks, and describes the general arrangements of a basic open-hearth plant in the United States, and the chief points in which it differs as compared to an European open-hearth plant employing the same process.

A description has appeared[†] of the plant under construction at Kinkora, New Jersey, for the Roebling Company. There will be three 30-ton furnaces and one 50-ton furnace using the acid process, as the product will consist almost entirely of high carbon steel. Blooming and wire mills will also be laid down.

The extensions of the open-hearth plant of the Pennsylvania Steel Company, Steelton, Pennsylvania, are briefly described.[‡] There will be five stationary open-hearth furnaces, each of 70 tons capacity. Gas will be produced by Hughes' mechanically-stoked gas producers.

The projected new plant of the Indiana Steel Company, Michigan, is described.[§] When completed there will be 84 open-hearth furnaces of 60 tons capacity each. At present two units are under construction, each of which will be 1190 feet by 206 feet, with charging floors 80 feet wide and pouring floors 60 feet wide, the latter having four pouring platforms. Each building will have fourteen furnaces of 60 tons capacity. The charging floors will be served by 75-ton electric cranes, and the pouring floors by 125-ton cranes. The charging floors will open into the storage yards; they are 72 feet wide, extending the entire length of the building, and each is served by a 5-ton crane. At the end of each open-hearth group nearest the blast-furnaces are the mixer buildings, 86 feet by 120 feet. The mixers are of 300 tons capacity and will be operated by hydraulic power. The ladles will be handled by 75-ton electric travelling cranes, having 15-ton auxiliary hoists.

III.—*THE BESSEMER PROCESS.*

Small Bessemer Plant.—Alexander Zenzes[||] describes a small Bessemer plant with a 1-ton converter for a production of about 10 tons of steel per week. The blast is supplied by a rotary blower driven by means of a belt by a 70 horse-power electric motor. The duration of the blast must be as short as possible—ten to fourteen minutes. The converter has two rows of tuyeres, of which the upper row is only used when necessary. Particulars are given of the charge and of the cost of the plant.

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[*] *Mémoires de la Société des Ingénieurs Civils*, 1906, No. I. pp. 373–382.

[†] *Iron Age*, vol. lxxvii. p. 1399.

[‡] *Ibid.*, p. 2051,

[§] *Engineer*, vol. cii. pp. 340–341.

[||] *Giesserei Zeitung*, vol. iii. p. 239.

Basic Bessemer Practice.—J. Lormier * deals with the progress made in plant, materials, and practice in basic Bessemer steel manufacture, beginning with brief descriptions of the earliest plant and accessories, and proceeding to trace the development by periods. Thus he deals with the conditions prevailing in 1894 and in 1900, which he contrasts with those prevailing at the present time (1906). He points out that whereas the materials employed are practically similar to those formerly used, current practice has proceeded along the lines of greater speed in the actual operations concerned, and in reducing the length of the blow. The mixer is comparatively a new device, but otherwise the conditions have altered but little during the last six years.

H. Crowe † gives an account of recent Bessemer steelworks practice in Germany, deduced from observations made in a recent visit to that country. The tendency is to lay down large mixers, which are frequently built in pairs of 500 tons each. Gas-firing is frequently employed.

Bessemer Steel Practice in America.—G. Rivière ‡ describes the chief points of difference between Bessemer steel practice in the United States and in Europe. He points out that the acid process is practically the only one employed in the United States, where the nature of the ores is such as to preclude the production of pig iron suitable for basic Bessemer practice.

An illustrated description has appeared § of the new Bessemer steel plant of the Youngstown Sheet and Tube Company, East Youngstown, Ohio. The cupola building is equipped with four cupolas, 10 feet in diameter and 20 feet high. In the converter-house there are two 10-ton converters, with a complete equipment of cranes, buildings for making converter bottoms, and a furnace for pre-heating ferro-manganese and spiegeleisen. There is one compound horizontal blowing-engine and two horizontal cross compound duplex pressure pumps.

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* *Bulletin Technologique*, 1906, pp. 651–696.

† *Engineering*, vol. lxxxi. p. 774.

‡ *Mémoires de la Société des Ingénieurs Civils*, 1906, No. I. pp. 366–372.

§ *Iron Age*, vol. lxxviii. pp. 259–267.

The Metal Mixer.—S. F. Perin * points out that although the introduction of the metal mixer dates back only about a dozen years, its use has now become almost universal at works where basic steel is produced. Indeed it has proved itself the most practical as well as the cheapest method for rapidly reducing the percentage of sulphur, the employment, for this purpose, of a heavier burden of limestone, or the use of manganese ore, being both dearer and less certain in operation, while processes such as that of Saniter and others have failed to prove of general practicability. He suggests that the installation of a mixer should prove highly beneficial to pig iron makers even when there is no steelworks adjoining. The quality of the pig iron will be greatly improved and, besides containing less sulphur, the pigs will be much cleaner and more uniform. The handling of the mixer may be by steam-power or by electricity. He then discusses the reactions which occur in the mixer. Hitherto it has been regarded only as a mixer, and the part it plays in eliminating a proportion of the sulphur has been relegated to the second place. The quality of the pig iron made in a blast-furnace depends upon so many factors and is subject to such sudden and unforeseen alterations, that the greatest difficulty is met with in practice in regulating the grade of pig iron produced. In these circumstances the mixer was regarded as a valuable means for mingling the results of several casts, and obtaining a more regular description of iron. It was Massenez and Hilgenstock who first diverted the mixer from its original object, and showed that it might be employed to reduce the sulphur present in pig iron, previous to using it in the basic Bessemer converter. The process by which sulphur is eliminated is simple. The element is present in the molten metal, as sulphide of iron (FeS), but also frequently in the condition of manganese sulphide (MnS). Its elimination depends upon the formation of sulphur dioxide, SO_2, which can only be accomplished in the blast-furnace by employing calcium compounds, with the resulting formation of calcium and manganese sulphides, which pass out into the slags. In the metal in the mixer there always remains a small amount of manganese sulphide, which is constantly reduced by the oxygen of the air, with the formation of manganese monoxide and sulphur dioxide, which escapes. The manganese oxide, after a cycle of reactions, combines with a further proportion of sulphur, manganese sulphide is regenerated, again decomposed, and the cycle of operations repeated. In the intermediate reactions the presence of silica plays an important part, while the length of time the metal remains in the mixer is also an important factor in the ultimate result. The silica is derived from the bricks of the lining, and the foregoing reactions account for the scouring effect of the bath upon that lining. A number of analyses in support of the foregoing statement are given, while the thermal reactions which occur are instanced as affording further evidence of the accuracy of the view taken. The smell of burning sulphur, noticeable at the surface of the slag in the mixture, is a further proof of the escape of sulphur by this means. In other words, the manganese acts as a carrier for sulphur, which it constantly liberates. He next deals with the construction of the mixer. Different shapes have from time to time been proposed for this vessel, but the principles involved have been the same in each. One of the earliest types was that constructed by Daelen. Langheinrich has collected illustrations and descriptions of the forms used in America. In European practice the mixer usually resembles in form the Bessemer converter. A detailed description of the mixer installed at the author's works at Micheville is then given. Its capacity is 150 to 200 tons. The dimensions, linings, and the appliances for tilting and pouring are fully described. The question of linings is most important, in view of the part they play in the desulphurising cycle of reactions. As long as the mixer was regarded as a simple vessel for receiving large quantities of molten metal, and retaining it in that condition, ordinary silica bricks sufficiently refractory to withstand the temperatures reached were all that was required. The severe scorification which occurred at the slag line showed that something else occurred, and that linings were required which should be capable of resisting chemical action, as well as the influence of the temperature. Magnesia bricks proved satisfactory, but their high cost caused many firms to prefer expensive renewals of silica courses rather than undertake the heavy cost of using magnesia brick linings. The suggestion of using dolomite and lining the mixer similarly to the converter would appear a sound one, in view of the apparent similarity of the conditions to which the two vessels are exposed in practice. Actual attempts in this direction failed, however, and it became recognised that a number of important differences really existed, which rendered comparisons useless from this point of view. It was found necessary to revert to magnesia bricks, but, as the corrosion only occurred on the slag line, only the zone exposed to the action of the slag was built up of such bricks, and the cost proportionally reduced. The arrangement adopted is illustrated, and the method of laying the courses described. The drying of the mixer, preparatory to using it, is then discussed. A log fire is first lighted, and after a preliminary drying by this means, coke is introduced, the combustion being aided by a low air-blast from the blowing-engines. The mixer is then tilted to remove the ashes and unburned coke. The time of casting from the blast-furnace is adjusted so that, so far as possible, it may be practicable to pour into the mixer four or five successive casts of pig iron at intervals of twenty minutes to half-an-hour, in order to avoid heat losses. An addition of 40 to 100 lbs. of spiegel, containing 10 to 12 per cent. of manganese, is beneficial at this stage, so that the first 150 tons of metal may have about double the normal proportion of manganese. This serves as a reserve, and facilitates the subsequent desulphurisation. It is highly necessary to avoid introducing slag into the mixer, and to pour off as much slag as may be found expedient from the surface, as the reactions take place at the surface of the bath, and in contact with the atmosphere, while these reactions largely conduce to maintaining the temperature of the metal. In using a mixer it is highly necessary that the contents should never be allowed to become too small, or with the resulting loss of heat the metal may solidify. The needs of the steelworks should be made subservient to this necessity, and there should always be a sufficient reserve of metal retained, even if the converters have to wait for their supply. A number of analyses are given, showing the improvement in chemical composition which the use of a mixer confers on the metal, with special reference to the desulphurisation which occurs. The average reduction in this constituent is 45 to 48 per cent. of the original amount. About 25 per cent. of the original amount of manganese is lost in the reactions, and 33 to 43 per cent. of silicon, while the total loss involved in the use of the mixer amounts to about 1 per cent. of the weight of metal charged.

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* *Revue Universelle des Mines*, vol. xiii. pp. 115–148, with twenty-five illustrations.

The Ebbw Vale Steel Company * has installed a mixer of 750 tons.

O. Simmersbach † discusses the form of pig-iron mixers provided with separate heating arrangements. One of those described is

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* *Stahl und Eisen*, vol. xxvi. p. 363.

† *Ibid.*, pp. 1234–1240, with four illustrations.

intended to deal with 150 tons of molten pig iron, and is to be heated with gas and pre-heated air. Another has a capacity of 250 tons, and is heated by gas and cold air. It is of the tilting type. Another such form of tilting mixer is also given, and it is pointed out that hydraulic tilting arrangements are better than electric ones. A fourth type of such mixers is also described, and the author points out that in recent years the capacity of steelworks mixers has been increased to 700 tons, whilst for foundry purposes mixers with external heating have been constructed of 60 tons capacity.

FURTHER TREATMENT OF IRON AND STEEL.

Hardening Steel.—A list is given of all the papers and paragraphs dealing with the hardening of steel which have appeared in the *Oesterreichische Zeitschrift für Berg- und Hüttenwesen* * since its establishment—a period of fifty-four years.

The process of hardening steel is described by C. Wadeck.†

F. Kick ‡ refers to various points of practical importance in the hardening of steel. Various methods are referred to; and the hardening of some difficult forms briefly described. The softening and hardening of high speed drill steels is also described, and the use of the electric furnace briefly mentioned. The methods originally solely employed for hardening the high speed steels consisted in blowing a rapid stream of air on the hot metal.

J. H. Heckel § deals with the hardening of steel from the practical point of view, and the faults that occur in connection with it. The right kind of steel should always be taken for any particular use to which the tool may have to be put. The separation of the piece of steel needed is next referred to. First to nick one side, and then to knock off a piece with a hammer is a common though bad practice, as it will lead to cracks in the metal. The proper annealing of the steel before treatment is most important, as the author shows, and he then proceeds to deal with the hardening process proper. To ensure treatment at the proper temperature no sunlight should be allowed to enter the place used for the hardening. Many other matters are referred to, the rapid working steels being also dealt with.

A furnace in which a current of electricity replaces the usual sources of heat in melting the lead or heating the salt bath to be used for hardening purposes, has been devised by Körting Brothers.* Every desired temperature from 750° C. to 1325° C. can be obtained in this way. Ordinary tool steel is hardened at a temperature of about 350°, but for high speed steels the temperature is from 1000° to 1150°, while for certain kinds even as high a temperature as 1300° C. is needed.

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* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 234–236.

† *Giesserei Zeitung*, vol. iii. p. 164.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 449–453, with eight illustrations.

§ *Ibid.*, pp. 541–544 and 558–560.

A special form of electrical furnace designed for hardening tool steel is described.† It is especially difficult to obtain the temperature of 1300° C. necessary for the hardening of steel for high-speed tools, or to keep it constant in any furnace not heated by electricity, owing to the fact that no crucible will withstand this high temperature continuously. In this furnace the metallic salt or mixture is brought into the molten condition by an electric current passing through it, thus providing a bath into which the pieces of metal to be heated are placed. The current flows through every part of the bath alike, thus ensuring uniform heating. By simply regulating the current it is possible to attain any temperature between 750° C. and 1325° C. For hardening ordinary tool steel a temperature of 850° C. suffices. For hardening high-speed steel temperatures of 1000° to 1150° C., and for special kinds up to 1300° C., are required. The temperature should be taken after starting up by means of a pyrometer and checked from time to time during the shift. As a rule, however, the ammeter-reading is a sufficient guide for this purpose. The energy consumption per cubic inch of the bath mixture, at a temperature of 750° C., is about 4·10 watts; at 800° C., about 7·05 watts; at 850° C., about 9·85 watts; at 1000° C., about 23·00 watts; at 1150° C., about 36·10 watts; and at 1300° C., about 49·20 watts.

Manufacture of Steel Dies.—J. Wienke ‡ describes the cutting and general preparation of steel dies. The die-sinker's art flourished in very early times, but was lost and only revived again in the fourteenth century.

Welding.—The electric method for welding rails together has been employed at several German towns. The way this is performed is described by Stahl.§ Comparing this process with that of Goldschmidt, the author thinks that this latter method is preferable for new work, and the electric method for welding together old metal such as tramway rails, the electric method being inversely less suitable for new work than for old.

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* *Stahl und Eisen*, vol. xxvi. pp. 1019–1020, with six illustrations.

† *Iron and Coal Trades Review*, vol. lxxiii. pp. 120-121.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 211-214, with eight illustrations.

§ *Stahl und Eisen*, vol. xxvi. pp. 1024–1025, with three illustrations.

It is stated by Stahl * that the Goldschmidt method was utilised by the authorities of the town of Düsseldorf in 1905 for welding together old tramway rails. The way this was performed is described.

A. Bousse † observes that whatever methods or appliances are used in the manufacture of gas-pipes one thing is always needed, and that is a furnace in which the metal strips to be made into gas-pipes are first raised to the right temperature. Indeed, this is looked upon as the most important part of the whole plant. The furnaces so employed are described and illustrated by the author, and he compares the early and the recent forms of such furnaces. The construction of a modern furnace and the materials used are also discussed.

Compression of Steel Ingots.—W. H. Ellis‡ gives an account of recent practice in compressing steel ingots, with special reference to the Harmet process.

The Harmet process of compressing steel is described by H. Wiecke.§ He gives details of the cost of the plant needed for compressing fluid steel by the Harmet method, as well as of the working charges.

E. L. Dickenson ‖ discusses the occurrence of pipes in steel ingots and their causes, with special reference to the compression of steel ingots.

Blowholes in Steel.—A. Ruhfus ¶ deals with the question of the influence exerted by the composition of the producer-gas on the formation of blowholes in open-hearth steel. He has made numerous analyses, and the maximum percentage of hydrogen he has found in the gas from fluid steel was 27·46, together with 52 per cent.

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* *Stahl und Eisen*, vol. xxvi. pp. 1023–1024.

† *Ibid.*, pp. 602–607 and 658–661, with ten illustrations.

‡ Paper read before the Sheffield Society of Engineers and Metallurgists; *Engineering Review*, vol. xiv. p. 297.

§ *Zeitschrift des Vereines deutscher Ingenieure*, vol. l. pp. 1279–1282; *Bayerisches Industrie- und Gewerbeblatt*, 1906, No. 28, p. 287; No. 29, p. 297; *Stahl und Eisen*, vol. xxvi. pp. 628–629.

‖ Paper read before the Sheffield University Students' Engineering and Metallurgical Society; *Engineering Review*, vol. xiv. p. 377.

¶ *Stahl und Eisen*, vol. xxvi. pp. 775–777, with five illustrations.

of carbon-monoxide and 7·4 of carbon-dioxide. This was an ingot metal low in carbon, and the temperature was at least 1400° C. The presence of gases in steel is in the first instance dependent on the composition of the pig iron used, and of the steel produced from this. Hydrogen appears to be readily absorbed, but the presence of carbon-monoxide appears to facilitate its separation. The smaller the ingots and the more rapid their solidification, the more gas will they contain. The author gives illustrations of samples taken during the open-hearth boil at intervals of fifteen minutes, and rapidly cooled in moulds. As the temperature grew higher and the steel more fluid, the blowholes concentrated more towards the centre, and gradually grew smaller and smaller in quantity, disappearing entirely in the finished metal.

High-speed Steel.—O. M. Becker[*] gives the results of experience with high-speed steel in the factory, giving particulars of the range of adaptability of alloy steel tools, and of the conditions of maximum effect with tools.

The development of high speed steel in Germany is traced by O. Thallner.[†]

Steelworks Equipment.—Illustrations[‡] are published of a new heating furnace for ingots or billets, designed to take twenty of these, each weighing 0·3 ton, at one time.

Illustrations,[§] accompanied by descriptions, are published of a number of cranes and other appliances for use in smelting works. Included amongst these is a heatable pig-iron mixer of 250 tons capacity.

In connection with an illustration of a hydraulic plate-shears of German design,[‖] it is pointed out that such shears usually work with only one pressure cylinder, with the result that whatever the work the same quantity of water must always be used. The new shears, on the other hand, allow of fifteen modifications. It will take plates 1·97-inch in thickness and 14 feet 9 inches in width.

C. von Ernst[¶] refers to the apparatus devised by Reese of Pittsburg twenty-five years ago, by which a rapidly rotating disc was made to cut through a steel bar very rapidly without even touching it. The disc was 0·75 inch thick, 42 inches in diameter, and, making 230 revolutions per minute, attained a rim velocity of 2500 feet per minute. A steel bar 1·625 inch thick was cut through in from two to ten seconds. The progress made since then is referred to, and American articles dealing with this subject mentioned. At present the process is used for cutting through hardened armour-plate. The theory of the process is still not understood.

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[*] *Engineering Magazine*, vol. xxxi. pp. 231-246, 397-405, 712-721.

[†] *Zeitschrift des Vereines deutscher Ingenieure*, vol. l. pp. 1690-1697.

[‡] *Stahl und Eisen*, vol. xxvi. pp. 1274-1275, with two illustrations.

[§] *Ibid.*, pp. 925-932, 997-1006, and 1117-1123, with thirty-three illustrations.

[‖] *Ibid.*, pp. 1255-1256, with one illustration.

[¶] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 137-138.

Steel Sleepers.—An illustrated description has appeared * of a new form of steel railway sleeper, designed to equalise and distribute the stresses which occur in practice. The tie is so constructed that all parts are interchangeable, and is so arranged that a curve may be produced by the adjustment of the ends of the tie without varying the alignment.

W. F. Miller † discusses the relative advantages and disadvantages of steel sleepers compared with wooden sleepers on railways. He gives the chief sections which have been devised for sleepers, and compares their first cost and the average life of steel sleepers with those of ordinary wooden sleepers.

Steel Rolling-Stock.—G. H. Sheffield,‡ in dealing with steel rolling-stock, gives a history of the introduction of material other than timber into railway carriages, and states that he had met with several instances of rapid corrosion of iron and steel plates, flitched into oak sole-bars, and of flanges and webs of steel channel sole-bars in contact with oak floors.

A. Stucki § describes the use of steel castings in railway waggon building.

Rails.—The works of the English McKenna Process Company, Ltd., at Seacombe, Birkenhead, are figured and described.‖ The process employed is one which has been in operation eight or nine years past in America, and results in the production of new rails from old ones by re-rolling them to slightly smaller sizes. The sequence of operations is described, and the furnaces, chargers, &c.,

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* *Iron Trade Review*, April 12, 1906, pp. 26–27.

† *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xxii. pp. 69–96.

‡ *Times Engineering Supplement*, 1906, p. 143.

§ *Railroad Gazette*, vol. xl. pp. 600–601.

‖ *Engineering*, vol. lxxxi. pp. 262–266, 296–298, 375–376, 430–441, with forty illustrations.

illustrated. The total length of the main roll train is about 422 feet. It contains six pairs of rolls. The hot-bed and cambering machine and the accessory appliances are fully described.

Standardisation of Sections.—E. Bernheim * discusses the standardisation of iron and steel sections and specifications in Great Britain. He deals in detail with the reports of the Engineering Standards Committee on rails and fishplates, both for tramways and railways, and also on specifications for the materials used in the construction of locomotives and in electrical engineering.

Sir J. Wolfe Barry † deals with the progress of the principle of standardisation in structural shapes and engineering sections, and traces the history of the movement from the time of the establishment of the Engineering Standards Committee. He reviews the work of that Committee, and summarises the results obtained up to the present, and the advantages to be anticipated from the regularisation of such sections and the achievement of uniformity.

A. Hertwig ‡ discusses the need for improving German standard sections for girders. The subject is also dealt with by A. Sommerfeld.§

The section book issued by the Differdingen Works, Luxemburg, is discussed from a mathematical point of view by G. Mehrtens.‖

Steel for Structural Purposes.—The requirements to be met in fire-proofed steel construction are discussed by W. S. Smith. ¶

The behaviour of the steel structures employed for office and other buildings in San Francisco during the earthquake of 1906 and the subsequent fire is described.**

The effects of earthquake and fire on modern steel buildings at the San Francisco disaster are also discussed by C. Heller,†† by G. Mitchell,‡‡ by C. G. Hyde, §§ and by the State Earthquake Commission. ‖‖

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* *Annales des Mines*, vol. ix. pp. 722–745.

† Paper read before the British Association at York, August 3, 1906; *Mechanical Engineer*, vol. xviii. pp. 285–288.

‡ *Zeitschrift des Vereines deutscher Ingenieure*, vol. l. pp. 1098–1104.

§ *Ibid.*, pp. 1104–1107.

‖ *Ibid.*, pp. 496–499.

¶ *Iron Age*, vol. lxxvii. p. 1609.

** *Ibid.*, pp. 1412-1414.

†† *Engineering Magazine*, vol. xxxi. pp. 526–539.

‡‡ *American Architect*, June 2, 1906.

§§ *Engineering Record*, vol. liii. June 2, 1906.

‖‖ *Mining and Scientific Press*, June 16, 1906.

George Simpson [*] also deals with the effects of the San Francisco earthquake and fire, and describes how the structures built of steel and reinforced concrete behaved. The steel frames were, generally speaking, not damaged by the earthquake, while concrete acted excellently as a fireproofing in the subsequent fire. The bulk of the damage would appear to have been done by dynamite, which, in view of later events, he considers was unnecessary.

Reinforced Concrete.—The number of memoirs published on the subject of reinforced concrete rapidly increases, and many important articles have been published in the periodicals *Beton und Eisen* (Berlin), and in *Concrete* (London), a new illustrated monthly journal. In Berlin a series of research memoirs [†] relating to reinforced concrete is in course of publication. Chief amongst these are treatises by F. von Emperger on the bond between concrete and steel as a measure of the bearing strength of reinforced concrete beams, and by E. Probst on the working together of concrete and steel, based on laboratory tests.

The discussion upon steel and reinforced concrete at the seventh International Congress of Architects, London, [‡] was responsible for a great number of valuable papers being read. These include papers on the aim of the joint reinforced concrete committee, on ferro-concrete construction by Henry Adams, and on steel and reinforced concrete constructien by J. Bassegoda.

In a paper read before the Institution of Mechanical Engineers at Johannesburg, H. Kestner [§] deals with ferro-concrete. J. E. Howard [||] gives the results of plain and concrete column tests at Watertown Arsenal. D. B. Luten [¶] discusses the comparative advantages of hard and soft steel for reinforced concrete. R. Saliger [**] discusses the best proportions for reinforced concrete beams.

E. N. Hunting [††] deals with the application of reinforced concrete to workshop construction.

W. N. Twelvetrees [‡‡] gives a number of instances of recent practice in the design and construction of concrete steel.

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[*] *Iron Age*, vol. lxxvii. pp. 1815–1828, with thirty-five illustrations.

[†] *Forscherarbeiten auf dem Gebiete des Eisenbetons.* (Berlin: W. Ernst & Son.)

[‡] *Journal of the Royal Institute of British Architects*, vol. xiii., Part IV., pp. xxvi–xxxii.

[§] *Architect*, June 22, 1906.

[||] *Engineering News*, vol. lvi. pp. 20–21.

[¶] *Ibid.*, pp. 62–64.

[**] *Oesterreichisches Wochenschrift für der öffentlich. Baudienst.*, July 7, 1906.

[††] Paper read before the American Society of Civil Engineers; *Engineering*, vol. lxxxi. pp. 357–359.

[‡‡] *Engineering Review*, vol. xiv. pp. 261–267, 328–330.

G. Espitallier [*] discusses the methods of ascertaining the strength of reinforced concrete, and gives formulæ for ascertaining the ultimate strength of various sections, and the methods of treating reinforced concrete structural material.

A description is given by J. M. de Zefra[†] of a large loading staithe for iron ores, recently constructed for the Société des Mines de Cala, on the Guadalquivir, near Seville. Reinforced concrete has been used throughout.

With the enormous use of reinforced concrete in the United States there has developed a discussion as to the best kind of steel to use.[‡] One faction advocates the use of bars "deformed" by twisting, transverse corrugations, flattened portions, &c., so as to give a mechanical bond or grip for the concrete. The opposite faction sees no advantage in this, but employs ordinary merchant bars of round or square section. Then, again, one party favours the use of steel having an elastic limit of 55,000 lbs. to 60,000 lbs. per square inch, while another favours steel having an elastic limit of 35,000 lbs. to 40,000 lbs.; the harder steel is usually advocated by those interested in "deformed" bars. If hard steel is to be used in less percentage than soft steel on account of its greater tensile strength, it will, of course, present less adhesive surface, and should be used in smaller sizes to offset this difference. As a rule, ¾-inch rods are the largest desirable, and ⅝-inch and ½-inch rods are generally preferable if they do not interfere too greatly with the placing and packing of the concrete. Round bars have less area than square or flat bars, but are much more easily embedded in the concrete, as it is difficult to ensure close contact between concrete and the bottom of a square or flat bar. Square bars should, therefore, be set in diamond position, or with inclined sides. It is concluded from investigation that if hard steel and soft steel are readily procurable in trustworthy quality at the same cost, neither possesses any marked advantage over the other for reinforcement, and steel of any usual elastic limit may be used in properly-designed structures without reference to its percentage of carbon.

The use of high carbon steel bars for reinforcing concrete is recorded.[§]

The resistance to shearing stresses, and the methods for securing adhesion of the concrete in reinforced concrete, are discussed.[‖]

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[*] *Génie Civil*, vol. xlviii. pp. 161–163.

[†] *Ibid.*, pp. 121–124, with sixteen illustrations.

[‡] *Engineer*, vol. cii. p. 227.

[§] *Iron Age*, vol. lxxvii. p. 1323.

[‖] *Engineering*, vol. lxxxi. pp. 22–23.

An illustrated description is given * of the Johnson indented steel bar for reinforced concrete. It is claimed on behalf of this bar that a higher working stress can be used than can be adopted for soft steel bars, owing to the elastic limit being very high. Cracks in the concrete cannot penetrate to the indented bar so long as the stress in the steel is within the elastic limit. A further advantage is that as the bars are formed direct by the rolls, they are all alike, their shape in no way depending upon the personal equation of the workmen. The metal used in their manufacture is a special high carbon steel, having an elastic limit of about 55,000 pounds per square inch. Tests of results obtained by Spofford and Constant are given.

Steel Chimney.—James Hebbard † gives a detailed description, with numerous illustrations, of the erection of a steel chimney 120 feet high at Broken Hill.

Shipbuilding.—Robert Curr ‡ describes shipyard methods of steel ship construction, giving particulars of the work on the *J. Q. Riddle*, which was built and launched in forty-five days at Lorain, Illinois.

The design and construction of steel barges used in river transport are figured and described by R. J. Donovan.§

Armour-Plate.—W. E. Edwards,‖ in dealing with modern armour and its attack, gives a very complete and useful history of the application of armour to ships and forts, and explains in detail the elaborate and costly processes through which the material passes, from the casting of the steel ingot to the completion of the plate.

Manufacture of Tinplates.—R. Beaumont Thomas ¶ gives a description of the tinplate trade, and deals with its history and development. The manufacture of tinplates in Great Britain was first started by John Hanbury, at Pontypool, in the year 1720, and a large number of works were soon opened in Monmouthshire and the neighbouring counties. In 1849 the export of tinplates was a leading feature, and the trade has more than doubled itself every ten years up to and including 1891, when the trade reached its maximum output. A chronological account of the principal events in the history of the industry is given, from the earliest date (A.D. 23) at which tin-coated iron vessels were known to exist, to the installation in 1905 of the first electric-driven tinplate mill in the world, at Tynewydd, Melingriffith, Gorseinon. The full sequence of operations, from rolling and annealing to picking, tinning, cleaning, sorting, and packing, are then described. The electrically driven tinplate mill recently put down by the Redbrook Tinplate Company, Tynewydd Works, has a three-phase induction motor, which takes current from the South Wales Electrical Power Distribution Company's system at 2200 volts pressure, and a frequency of 25 cycles. It is rated at 100 brake horse-power, and has a synchronous speed of 250 revolutions per minute. The load in tinplate rolling is very variable, and the maximum load reaches two-and-three-quarter times the normal; that is, when the piece passes into the rolls. At this overload the motor shows no tendency to fall out of step or to overheat.

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* *Engineer*, vol. ci. p. 580.

† *Transactions of the Australasian Institute of Mining Engineers*, vol. xi. pp. 71–76.

‡ *Marine Review*, August 2, 1906.

§ *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xxi. pp. 520–536.

‖ Paper read before the British Association, August 2, 1906.

¶ Paper read before the Cardiff Meeting of the Institution of Mechanical Engineers; *Iron and Coal Trades Review*, vol. lxxiii. pp. 496–500.

A baling press for dealing with scrap and tinplate, manufactured by the Famous Manufacturing Company, East Chicago, Indiana, is figured and described.*

Enamelling Cast Iron.—R. Vondracek † states that the enamelling of iron differs from that of other metals, by the iron chemically reacting as a carbon alloy with the applied enamel when being burnt in, whereby the appearance and durability of the enamel suffer. This specially happens when the enamel contains substances which can be reduced, such as dioxide of tin and oxide of lead. An enamel of this kind should never be applied directly to cast iron. The object in practice is to give the enamel such chemical properties that it does not react on the carbon of the iron, or to modify the surface of the casting to render the action of the carbon impossible. The first method is seldom employed for white enamels, because only enamels which are easily fluid and of little resistance can be so prepared. On the other hand, coloured enamels are often prepared in this manner. The second means is often employed. The principal method employed consists of placing an intermediate coating between the enamel and the iron, which must be sufficiently refractory not to penetrate the enamel during the process of burning-in. It is often stated that the different coefficients of expansion of iron and enamel are not compensated by this coating. Copper-plating of iron has little effect. In theory the correct method is thoroughly to remove the carbon from the surface of the iron, but this can hardly be realised in practice.

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* *Iron Age*, vol. lxxvii. p. 1397.

† *Chemiker Zeitung*, vol. xxx. pp. 575–577.

Small Ironwork.—Instances of work done by the Vienna service for the promotion of arts and crafts were shown at the Austrian Exhibition at Earl's Court. Illustrations have been published [*] of the work of the smiths in the Stubai Valley, to the south-west of Innsbruck; of those at Ybbsitz, on the path of the old Niebelungs, on the Danube, in Lower Austria; of the cutlers and smiths in the district of Steyr, in Upper Austria; and of the gunmakers at Ferlach (Carinthia).

Damascening of Metals.—The damascening and inlaying of metals is dealt with by S. Cowper-Coles.[†]

Galvanising.—Recent progress in galvanising is summarised by H. Stockmeier.[‡]

The Pottkoff method of cold galvanising, in addition to effecting an economy in fuel, prevents the material from undergoing any change in texture.[§] A description is given [||] of this process used by the United States Electro-Galvanising Company, at their works at Brooklyn, New Jersey. The process is a continuous one, and the solution is permanent, and does not have to be renewed. The handling is cheaper than by the hot process, fuel is saved, and the use of sal ammoniac is dispensed with, while the applicability of the process is almost universal. The coating can also withstand very rough usage without injury.

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[*] *Engineer*, vol cii. p. 224.

[†] *Journal of the Society of Arts*, vol. liv. pp. 738–748.

[‡] *Chemiker Zeitung*, vol. xxx. p. 343.

[§] *Bihang till Jernkontorets Annaler*, 1906, pp. 346–351.

[||] *Iron Age*, vol. lxxvii. pp. 1980–1982.

PHYSICAL PROPERTIES.

Specific Heat of Iron at High Temperatures.—J. A. Harker [*] has investigated the specific heat of iron at temperatures up to 1150° C. The specimens, cut to the shape of a cold chisel and weighing from 7 to 197 grammes each, are heated in a vertical tubular electric furnace, mounted on a swinging bracket; when the desired temperature, read off on a platinum resistance thermometer or on a thermocouple, is reached, the specimen is released, and dropped into the water calorimeter. As spring tongs would not answer at high temperatures, the specimens were suspended by a fine platinum wire hook, which was fused with the aid of a key and battery. Above 800° C. the iron becomes rapidly oxidised and disintegrates when falling into the water. Various means to stop this were tried—gilding the specimen, for instance, but the protective covering peeled off in the water. Pionchon had used sheaths of platinum for his specimens. It was finally found best to let the iron drop into a funnel tube charged with so-called light magnesia, which forms so loose a powder that the iron chisel sinks through 8 inches of magnesia as if the tube contained a liquid. This tube stands in the calorimeter. A sheath was still needed, however. Quartz sheaths cracked in the water, and reacted with the iron; porcelain sheaths were adopted, and their specific heat had, of course, also to be determined. The specific heat of the porcelain was found to be 0·2582 at a temperature of 912° C., and 0·2559 at 1075°. In this way the mean specific heat of iron has been found to increase from 0·1175 at 200° C. to 0·1647 at 850°, and to fall then to 0·1534 at 1100° C. These results are in close agreement with those found by Pionchon when the latter's temperature scale is revised.

Segregation in Steel Ingots.—J. E. Stead [†] deals with crystallisation and segregation in steel ingots. He gives methods for observing the macroscopical and microscopical structure of sections, and, taking into consideration the facts revealed by the cooling curve records, and the laws which govern the solidification of metals when cast in moulds, he explains how segregation in steel ingots occurs, and where it is likely to be found. The chilling effect of the sides and bottom of a mould, and of the air at the surface of a mass of steel in a fluid state, causes rapid freezing on the chilled surfaces and the formation of a number of minute crystallites, which develop to a very large extent in a rectilinear direction at right angles to the chilled surfaces. On the chilled outer layers the crystallites consist of closely packed solid stems with imperfectly developed side branches, a condition unfavourable for the entanglement of the mother liquor. As a consequence one would expect a part, at least, of the more highly carburised liquid would be pressed forward and be caused to comingle with the mass of the still liquid steel in the interior, and that the first layers would be relatively purer than the liquid. That such is actually the case is well known and is shown by the macrostructure. Observation has led him to conclude that of 100 parts of each element in the fluid steel, sulphur segregates the most, phosphorus follows the sulphur, carbon the phosphorus, whilst manganese and silicon do not appear to segregate to any material extent. Other conditions being equal, high casting temperature tends to produce axial segregation. Steel, near its freezing point when cast, will rapidly become solid, and little time will be available for the ascension of the lighter segregate, but if the temperature is excessive there will be ample time for it to rise. As a rule, at equal temperature of casting, the larger mass will be the more segregated. The author then deals with the concentration of purer steel in the lower central axis of ingots, and discusses the causes of laminated structure in rolled steel. He finds ample evidence that in rolled steels containing between 0·2 per cent. and 0·5 per cent. carbon, if the initial heating is above 900° C. and the cooling sufficiently protracted, the ferrite and pearlite frequently separate out into strings or bands. The ferrite containing the phosphorus and carbon when hot, in cooling rejects the carbon, which slowly diffuses out and is concentrated in the regions where there is less phosphorus and an excess of iron. This separation will take place even in Swedish Bessemer steel. On heating such steel to whiteness and quenching in cold water the carbon is found apparently regularly distributed, but etching polished sections of the hardened steel with exceedingly dilute etching fluids, the parts where the phosphorus bands exist, resist the attack and are left whiter than the other parts. The effects of segregation on the mechanical properties of steel are next discussed. He considers that failures in steel rails are in few cases due to segregation, but are caused by unsoundness. Compression of the liquid steel in the mould is the only reliable method of producing perfectly sound material, but the judicious use of either aluminium or carbon will contribute largely to this end.

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[*] *Report of the Executive Committee of the National Physical Laboratory for* 1905.

[†] *Proceedings of the Cleveland Institution of Engineers*, 1905–1906, pp. 163–216, with twenty-five illustrations.

Results illustrating segregation in steel ingots are given by C. L. Huston.*

Coarsely Crystalline Wrought Iron.—When a bar of Swedish iron made in the Lancashire hearth is broken with a sharp blow, a crystalline fracture results, whilst the same bar broken by slow bending shows a fibrous fracture. It sometimes happens, however, that the iron in the latter case also gives a crystalline fracture. Analyses published by G. Dillner † yielded the following percentages :—

With Crystalline Fracture.		With Fibrous Fracture.	
Carbon.	Slag.	Carbon.	Slag.
0·05	0·36	0·02	1·42
0·15	0·22	0·03	0·95
0·05	0·37	0·02	0·93
0·05	0·32	0·03	0·77

The crystalline structure may in this case be ascribed to the unusually low proportion of slag in the Lancashire iron.

Metallography.—M. Kralupper ‡ deals with the valuation of iron from its microscopic structure.

A description is given § of the metallurgical microscope designed by W. Rosenhain, who has pointed out that in the conventional microscope utility is often sacrificed to appearance. A number of innovations have been introduced, and the whole apparatus has been built up on engineering principles and is very strongly made.

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* *Iron Age*, vol. lxxviii. pp. 1–6.

† *Jernkontorets Annaler*, vol. lx. p. 248.

‡ *Zeitschrift des Oesterreichischen Ingenieur- und Architekten- Vereines*, vol. lviii. p. 385.

§ *Engineering*, vol. lxxxi. pp. 251–252.

P. F. Dujardin * deals with some points connected with metallographic technology. At first sight, he observes, metallographic methods seem difficult to undertake in practical work, but this is not so in reality. The method of preparing the sections, etching and photographing them, is discussed. The observation of cooling curves and other points are also dealt with.

E. Heyn † discusses at great length both metallography and its application in practice. Its most important scope lies in connection with the evidence it affords as to the thermal and mechanical preliminary treatment to which the metal has been subjected. After dealing with the changes which take place when steel is hardened, the author observes that quite similar alterations are observable in cold-worked mild steel, as for instance in connection with wire drawing. The influence of annealing is dealt with, and also the use that may be made of metallographic methods in explaining fractures. The main utility of such metallographic methods will lie, the author thinks, in connection with the more or less finished rather than with the unfinished material, as, for instance, in the final processes of manufacture and treatment of metal of special value.

J. O. Arnold ‡ deals with the microstructure of metals with reference to unexplained failures in boiler plates and the elucidation of the causes to which they are due.

T. Andrews § continues his microscopic observations on naval accidents. He deals with causes which led to the breaking of a boiler stay-bolt on H.M.S. *Melampus*, and gives photomicrographs of the fracture, and concludes, as the results of his examination, that for boiler stay-bolts steel is not such a good material as the best wrought iron.

E. Heyn || and O. Bauer have investigated the changes in structure in a steel containing 0·95 per cent. of carbon on hardening and tempering. Experiments were in the first instance made with a view to ascertaining a means for determining the approximate degree of

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* *Stahl und Eisen*, vol. xxvi. pp. 522–528 and 732–735, with eight illustrations.

† *Ibid.*, pp. 580–596, with fifty-one illustrations.

‡ *Engineering*, vol. lxxxi. pp. 278–279.

§ *Ibid.*, pp. 331–332.

|| *Mittheilungen aus dem Königlichen Materialprüfungsamt*, vol. xxiv. pp. 29–59; *Stahl und Eisen*, vol. xxvi. pp. 778–784, 915–922. and 991–997, with forty-nine illustrations.

annealing reached. These experiments led to some new views as to the constituents of the annealed metal. The steel used contained:—

Carbon.	Silicon.	Manganese.	Phosphorus.	Sulphur.
0·950	0·350	0·170	0·012	0·024

It was in the form of a square bar with sides of 0·98 inch. In its worked and annealed condition it consisted exclusively of pearlite. Sections 0·24 to 0·39 inch in thickness were cut off and quenched in water from a temperature of 900° C. It then consisted chiefly of martensite, with at times a quantity of troostite, varying according to the conditions pertaining to the hardening process. The composition of the steel was chosen so as to exclude the possibility of the presence of free ferrite or cementite, and so to make certain that the only constituents to be considered would be pearlite, martensite, and troostite or sorbite. The series of experiments are described and the results detailed. They tend to disprove the hitherto generally accepted belief in the gradual conversion of martensite into pearlite on annealing. Carbide carbon did not appear in the annealed steel until the temperature of 400° C. had been reached, and the former view that the contents of carbide carbon gradually increased with the temperature of the annealing process was found to be also incorrect. Samples annealed at about 400° C. show marked peculiarities. Between the temperature of 0° and 200° martensite, without further etching, becomes continuously darker. At about 275° from the martensite ground mass troostite has separated as a dark constituent. At about 400° as the annealing temperature the steel consists almost entirely of troostite. Above 400° a lighter coloured constituent begins to appear. As the temperature increases the ground mass grows more and more bright, and pearlite separates out as a granular constituent, which at 700° occupies practically the whole surface. There is a metastable constituent, that is, both below and above 400°, and with this the authors deal. Electro-conductivity, thermo-electric and magnetic curves are given. So long, the authors observe, as it is not found possible to produce iron carbide at a temperature of about 400°, it must be assumed that martensite is a solid solution of iron and already formed carbide. In their concluding remarks the authors observe that the change of martensite into pearlite with rising annealing temperatures is not constant, but that it passes through a well-defined transitional stage which they term osmondite. This corresponds to a temperature of about 400° C. The transitional stages between osmondite and martensite should be named troostite, and those between osmondite and pearlite should be termed sorbite.

Structure of Metals.—J. A. Ewing [*] deals with the structure of metals and their behaviour under strain, and adduces the molecular theory of magnetism to explain some of the alterations assumed by the crystalline particles. Reference is made to the work of Rosenhain on slip bands, and of Humfrey on fatigue. The theory advanced by Beilby that, under the influence of stress, portions of a metal may pass from a crystalline to an amorphous state, is accepted with certain reservations. For a given orientation of surface, the resistance to slip consists of two parts, one inherent in the surface itself, and the other derived from the position of the grain with reference to other grains. Thus in the case of steel the grains were of two classes—ferrite, which is simply iron and pearlite, which is a harder structure. Slip on any ferrite grain is resisted partly by the strength of the surface itself, and partly by the impossibility of its yielding without forcing slip to take place on neighbouring and harder grains. In the case of a very coarse structure, such as Stead has shown to exist in seriously overheated steel, the resistance to slip will be but little greater on the large grains of ferrite in overheated steel than it would be in iron. Consequently under an alternating stress fatigue of strength leading to rupture may be produced by a very moderate load. That the effects of overheating may be removed by raising the steel to a temperature sufficient to cause recrystallisation has been shown by Stead and Rogers, and the latter observer has shown that the overheated steel possesses, when properly reheated, a greatly increased power of resisting the effects of repeated stresses.

Magnetic Properties of Iron and Steel.—E. Wilson [†] deals with the phenomenon of self-induction in an iron cylinder.

F. Niethammer [‡] discusses iron losses in alternating current commutator motors.

A. Gradenwitz [§] describes devices for determining the energy losses in iron sheets.

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[*] Address to the Engineering Section, British Association Meeting at York, August 1906; *Electrical Engineer*, vol. xxxviii. pp. 154–158; *Engineering Magazine*, vol. xxxii. p. 112.

[†] *Proceedings of the Royal Society*, vol. lxxviii., Series A, pp. 22–27.

[‡] *Elektrotechnik und Maschinenbau*, vol. xxiv., June 10, 1906.

[§] *Scientific American Supplement*, June 23, 1906.

C. F. Burgess* and A. H. Taylor give the results of tests made to determine the magnetic properties of electrolytic iron. They point out that until recently iron of this description was in the nature of a curiosity, owing to the difficulty of depositing it in anything but thin layers. Recently it has been possible to make such iron in large quantities, as much as 1 ton having been produced, and plates nearly 1 inch in thickness and weighing 75 lbs. have been prepared. The specimens so far tested show a large amount of magnetic viscosity, which is the slow but very appreciable change of magnetic induction that takes place some time after the change in field has been made. The chief impurity is electrolytic hydrogen, but it is not known whether its presence affects magnetic qualities.

The effect of electrical oscillations on iron in a magnetic field formed the subject of a paper read before the Physical Society by W. H. Eccles.† In attempting to make precise measurements of the effect of high-frequency oscillations on iron held magnetised by a magnetic field, two main difficulties are met. The one is that arising from the fact that the oscillatory currents induced on the surface of the iron investigated shield the inner layers, and thus make the mass of iron affected a variable quantity. The other difficulty arises in the matter of producing oscillations of determinate and invariable character. The author has endeavoured to meet the first difficulty by using oscillations so feeble that they affected only the outermost layers of the iron wires employed, and these even only slightly. The second difficulty has been met by using the oscillations produced in an open insulated solenoid by a single small measurable spark passed to one end of the solenoid.

D. K. Morris‡ and G. A. Lister propose a standard test for transformers and transformer iron. The method involves but one set of connections, three instruments, and the normal supply, and necessitates the use of two similar transformers. It is a modification of that first described in 1892 by Ayrton and Sumpner, and is an application of the Kapp-Hopkinson or differential method of testing direct-current machines. The behaviour of a transformer when loaded at various power factors is, they find, best considered by means of a regulation diagram which they have constructed. The method of constant induced voltage affords a ready means of finding the true hysteresis loss, and is probably the best way of testing iron samples.

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* *Proceedings of the American Institute of Electrical Engineers*, vol. xxv. pp. 445–451.

† *Philosophical Magazine*, vol. xii. pp. 109–119.

‡ *Journal of the Institution of Electrical Engineers*, vol. xxxvii. pp. 264–294.

A. Campbell's* researches on the magnetic permeability of cast iron are described. In order to arrange the Ewing permeability bridge for testing cast iron and other materials, whose permeability differs considerably from that of the usually applied soft iron standard rods, some of the new standards have been given a tubular form, the outer diameter being kept constant, so as to fit the clamps, but the bore varying; pairs of these standards are tested by the Ewing yoke method, and the accuracy of the method is checked by ballistic tests with rings of the same material. The agreement is sufficiently good for practical purposes. Researches on the magnetic properties of chilled cast iron confirm and amplify the conclusion arrived at by B. O. Peirce, that magnets of chilled cast iron can, in galvanometers and other instruments, replace the much more costly magnet steel. A simple method of chilling has been devised. Investigations in hysteresis have also been made, but they have been delayed owing to the difficulty of obtaining suitable samples.

The magnetic properties of iron vary with time, and hysteresis and the after-effect in opposed direction. D. Mazzotto† has tested the effect of temperature and time on various qualities of iron, and concludes that the elementary magnets arrange themselves during time in closed chains. He describes the magnetising groups, and distinguishes three; the most rigid are at 131° C.

In his published experiment in 1874 Börnstein had, by the aid of magnetometric methods, been unable exactly to determine the influence of density on magnetising iron powder. Walter Trenkle‡ shows that this was owing to the insufficiency of the methods. By aid of a modification of the Joch method the course of magnetising was determined. The results obtained with rods of iron powder and clay pressed together can be summarised as follows: With equal magnetising force, the magnetising and susceptibility of pure iron powder is always greater than that of a mixture of iron powder with a substance that cannot be magnetised. The magnetic point of saturation of pure iron powder is always higher than the point of saturation of the diluted powder. If the massive iron rod is

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[*] *Report of the Executive Committee of the National Physical Laboratory for* 1905.

[†] *Physikalische Zeitschrift*, vol. vii. p. 262.

[‡] *Annalen der Physik*, vol. xix. pp. 692–714.

only distinguished from the rod composed of powder by its density, the magnetising of iron sinks with its density, and the magnetic value of saturation is so much smaller as the density is less. For this reason the necessary magnetic force to attain an equivalent value of saturation is greater for pure iron than for diluted. Variations of density are, as far as their influence on the course of magnetising, not to be compared with variations of the proportions of the dimensions of the cylindrical or elliptical form in which the material is to be examined.

P. Fournel* describes a method for determining the transformation points of steel by ascertaining their electrical resistances at different temperatures. The resistance was measured on a wire 0·3 millimetres in diameter, rolled round a double sheet of mica, and heated *in vacuo* in an electric resistance furnace. The wire was arranged in series with an ohm-meter, and a current of a few hundredths of an ampère passed through, the temperature being ascertained by means of a Le Chatelier pyrometer.

Effects of Heat Treatment.—R. A. Hadfield † points out that it is well known that chemical activity is greatly increased by a rise of temperature, and this may partly explain the extraordinary changes brought about in iron and steel when heat treated. Direct evidence on this point is difficult to produce. Profound changes do occur in the physical qualities of the iron or steel, as may be shown by the remarkable effect of heat treatment upon an ordinary carbon steel, of tool steel quality, having the following composition: Carbon, 1·16 per cent.; silicon, 0·07 per cent.; manganese, 37 per cent. Although it is generally known that such a steel will harden at certain temperatures, and will not harden at others, it was only quite recently discovered how fine is the dividing line—not more than a few degrees. S. N. Brayshaw even claims that but 1° C. will cause considerable difference in physical qualities. It is found that carbon steel of the composition mentioned, when heated to 725° C. and quenched in brine, will afterwards bend cold 43°, its Brinell hardness number being 228. Quenched at 735° C., or 10° higher, the quenched specimen, when cold, bends only 1·5°, the Brinell hardness number being increased to 512. Quenched at 740° C., the bend is nil and the hardness number 713; in other words, the steel is completely hardened. Thus by increasing the temperature only 15° C. complete hardening is obtained. Other important changes are those occurring both at lower and higher temperatures. Further, there are critical changes at the high temperatures of 900° to 1000° C., and these, it must be remembered, are temperatures at which forging and rolling are usually carried on. There are also variations in hardening temperatures. In dealing with changes of temperature, the influence of mass must be considered. At a given crystallisation produced by a given temperature a large mass will not necessarily behave in the same manner as a small one, and the duration of the heat treatment is also important. As instances of the importance of heat treatment, he adduces the hardness of the face of armour-plate, made to keep out projectiles, and that of the projectile, made to perforate the armour, the entire success or failure of the manufacture of which turns upon heat treatment. Profound magnetic changes are produced in iron by temperatures ranging from that of liquid air to that of high degree, 1000° C. or more. While the high nickel iron alloys and iron manganese alloys appear practically non-magnetic at atmospheric temperatures, upon cooling down in liquid air they become considerably magnetic, and remain in that state until again raised to about 500° C., when they become non-magnetic. This cycle can be carried out as often as desired with the same result. These structural changes must be very great, for the special steel containing 20 per cent. of nickel, which is almost non-magnetic or only feebly so, has a tenacity of 44 tons per square inch, an elongation of 55 per cent., a reduction of area of 63 per cent., and can be readily machined at ordinary temperatures. Upon being immersed in liquid air, however, it becomes strongly magnetic; its tenacity increases to the extraordinary figure of 157 tons, whilst its ductility still remains fairly high, namely 15½ per cent., and it can now only be machined with difficulty. This steel, after returning to atmospheric temperatures, retains a tenacity of no less than 115 tons per square inch, or more than two and a-half times that of its original condition, and has an elongation of 4½ per cent. The alloy of iron and manganese which he has invented is not affected by any change in temperature, whether the highest or that of liquid air; it always remains non-magnetic, except when annealed for a long period.

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* *Comptes Rendus*, vol. cxlii. pp. 46–49.

† James Forrest Lecture, *Minutes of Proceedings of the Institution of Civil Engineers*, vol. clxvi. pp. 190–223.

Heat treatment was discussed by H. M. Howe,* G. B. Waterhouse,

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* *Iron Age*, vol. lxxvii. pp. 2057–2058.

W. Campbell, J. Christie, and E. O. C. Acker, at the ninth Congress of the American Society for Testing Materials, at Atlantic City, New Jersey, on June 21 and 23.

Structural Changes in Nickel Steel Wire at High Temperatures.—H. C. H. Carpenter * describes the experiments he has made with the object of ascertaining the reason for a fundamental change in the mechanical properties of nickel wire used as the heating coil of an electrically-heated porcelain tube-furnace. During the investigation certain facts have been established relating to reactions between gases and solids under the combined influence of electricity and heat. In the furnaces employed the temperature of the wire increases gradually from about 70° to 80° C. in the double wire outside to 1300° C. in the thermal centre inside (which is not necessarily the linear centre of the tube unless the wire-winding is accurate); and accordingly the brittleness or fibrousness of the wire varies from a minimum outside to a maximum at the thermal centre. These gradual changes of mechanical properties are accompanied by gradual changes in the structure (though only to a very slight extent in chemical composition), which can be studied with the microscope, and whose sequence is remarkable for its continuity. Longitudinal and transverse sections of the wire taken from various parts of the tube have been examined. The changes in the properties of the nickel wire appear to be due mainly to two effects—viz., recrystallisation and the penetration of gases, which are themselves the result of heat and electricity on the metal. Gross crystallisation has for a long time been recognised as being frequently associated with brittleness in metals, and it does not seem necessary to draw special attention to this. But the evolution of dissolved or combined gas or gases from nickel and its mode of penetration through and eventual exit from it by means of cracks between the gross crystals, are, it is thought, described here for the first time. It appears from the analysis that the amount of gas present cannot be more than 0·02 per cent. by weight. Phenomena similar to those described may be expected to occur under similar conditions with any metal that contains occluded or combined gas. The gas will be set free and ultimately cause a revolution in the properties of the metal. Accordingly, wire intended to be used for electrical heating should be as free from gases as possible.

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* Paper read before the British Association at York, August 1906; *Engineering*, vol. lxxxii. pp. 222-223.

Nickel obtained electrolytically should contain less gas than that obtained by dry processes, and would probably prove superior in use. Difficulties, however, might still be encountered, arising from the vapour pressure of nickel itself at 1300° C. On various grounds it may be anticipated that platinum would be superior to nickel. (1) It melts at about 300° C. higher. (2) The only gas it absorbs at high temperatures in any quantities is hydrogen, and this it gives up on being heated in a vacuum. (3) When quite pure it may be heated far above its melting point in the oxy-hydrogen blast without any loss whatever by volatilisation. For these reasons it appears somewhat surprising that hitherto platinum has given results, very little, if at all, superior to nickel; and it would seem that a research into the cause or causes of the deterioration of the former metal in furnace use would be worth carrying out.

Strength of Cast Iron.—A. H. Hiorns * discusses the influence of various elements on cast iron.

The results of experiments relating to the bending strength of cast iron are published by H. Meyer.† Cast bars of 1·18 inch in diameter and 19·69 inches in length were used in the experiments, and the bending tests were carried out at the temperatures shown below. The baths used to heat the metal were of oil, lead, tin, and aluminium; a Krupp bending machine was used for the tests; and the temperature was determined calorimetrically. These experiments are subsequently to be described at greater length. The results now published are as follows for one set of tests:—

Temperature. Degrees C.	Bending Strength. Tons per Square Inch.	Bend. Inch.
18	23·53	0·31
66	22·22	0·30
268	21·08	0·28
297	19·88	0·30
620	12·09	0·55
807	7·56	0·94

A second set of similar tests gave the following results, which, it will be seen, are concordant with those just given:—

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* *Foundry Trade Journal*, vol. viii. pp. 293–299.

† *Stahl und Eisen*, vol. xxvi. pp. 1270–1271.

Temperature. Degrees C.	Bending Strength. Tons per Square Inch.	Bend. Inch.
18	23·58	0·30
85	21·90	0·28
155	21·27	0·28
370	21·02	0·30
580	16·13	0·57
810	6·16	0·79

The colours of the fractures were as follows:—

Degrees C.	Colour.
85	No change.
310	Grey violet.
460	Blue.
510	Blue grey.
670	Grey brown.
780	Black brown.
810	Black grey.

These experiments show unexpectedly that cast iron begins to weaken even at as low a temperature as 66° C. The temperature attained by saturated steam at 5·5 atmospheres is, however, as much as 155·85° C., and at this temperature cast iron is sensibly weaker than in the cold. The use of this material, therefore, needs careful watching.

Malleable Cast Iron.—In a paper read before the Scandinavian Technical Society, G. A. Akerlind * states that the tensile strength of malleable cast iron varies between 40,000 lbs. and 50,000 lbs. per square inch, with an elongation varying from 1 to 6 per cent. in a length of 6 inches, and a reduction of area of from $\frac{3}{4}$ per cent. to 3 per cent. respectively. Cast iron is therefore about half as strong as malleable cast iron. In compression cast iron is, however, much the stronger of the two. If lightness only is the object of using malleable cast iron, in the place of grey cast iron, it is customary in railway wagon construction to make a reduction in weight of 30 to 40 per cent. The reason, however, why malleable cast iron is now used to such a large extent in railway wagons appears to be not only the increasing demand for reduction in weight, but also owing to the rapid supplanting of wood by steel and the consequent substitution of rivets for bolts. Malleable cast iron permits the closing of rivets in a way that cannot be attempted with grey cast iron. For certain parts of the wagon, such as axle-boxes, malleable cast iron is much preferred to cast iron and "semi-steel," the preference being determined by its lightness. The author points out that, in designing malleable cast-iron details, it is important to keep the metal in the different parts of the casting at a uniform thickness, depending on the size and weight of the casting. In a small casting, say of about 10 lbs. weight, ¼-inch metal is about the right thickness, $\frac{5}{16}$-inch metal for castings of 15 lbs. to 20 lbs. weight, and ⅜-inch to ½-inch metal for castings of, say, 40 lbs. and over; but these weights particularly refer to castings for goods wagons. All sharp junction of ribs or parts should be carefully avoided, as in cast iron; and if the casting is long—24 inches or more—the ends should be made of such a shape as will offer as little resistance as possible to the contraction of metal when cooling in the mould. Malleable cast iron shrinks more in the mould than cast iron, but during the process of annealing a slight swelling takes place. If malleable castings have to be straightened by hammering, nothing is gained by heating them, a temperature of from 50° to 100° F. being satisfactory.

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* *Engineering*, vol. lxxxi. p. 853.

Tensile Properties of Steel.—J. E. Howard [*] points out that steel from the same ingot may display a wide range in tensile strength owing to variation in the methods of treatment, and gives a diagram showing the tests obtained on a low carbon steel which had been tested in the natural state of the ingot, and after being forged and subjected to heat treatment at different temperatures. The following results were obtained:—

Treatment.	Elastic Limit per sq. in. Lbs.	Tensile Strength per sq. in. Lbs.	Elongation per Cent.	Contraction of Area per Cent.
Natural state of ingot	17,000	54,880	15	21·4
Forged at yellow to bright red, cooled in air	46,000	64,960	31	57
Heated white hot, quenched in oil, annealed at cherry red . . .	38,000	65,280	15·3	30·6
Forged at blood-red colour, cooled in air	50,000	74,880	9	21·4
Forged at bright red, quenched in water	60,000	96,480	16	30·6
Heated white hot, quenched in oil .	45,000	96,600	6·3	13·2
Forged at white heat, quenched in water	40,000	110,880	10	36·4
Heated white hot, quenched in brine .	†	120,000	0·7	1·5

The steel tested had a chemical composition of 0·02 per cent. carbon,

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[*] *Iron Age*, vol. lxxvii. pp. 1404–1405.

† Elastic limit practically coincident with tensile strength.

0·58 per cent. manganese, 0·015 per cent. silicon, and 0·017 per cent. of phosphorus.

R. Guillery [*] suggests a method for the determination of the elastic limit of metals by obtaining a graphic record of the changing electrical resistance of the metal under stress. For this purpose a current of four or five volts, with an intensity of 26 to 30 amperes per square centimetre of the sectional area of the test bar, is passed through the latter and through a compensating resistance. A lead, soldered or clamped on to the head of the bar, connects the latter with a Carpentier ballistic galvanometer; whilst another lead connects the compensating resistance with the galvanometer, which can be adjusted to counteract the deviation set up, and to set the beam of reflected light opposite the zero mark. On starting the dynamometer, the fluctuations of the galvanometer record the varying electrical resistance of the test bar. At first a photometric method was employed, a thin vertical line of light being directed on to a slot in a camera containing a roll of sensitised paper; but this has been superseded by a device for recording direct on tracing paper or cloth. The paper is placed on a sheet of glass, and the latter is mounted on a frame that moves vertically between guides, the motion being automatically transmitted from the machine. As regards the results obtained, mild basic and acid open-hearth steels furnish almost identical data in respect of rupture, elastic limit, and elongation. Double annealing raises the elastic limit considerably, but prolonged heating at high temperatures has a contrary effect, though without altering the breaking strength or elongation of the metal. The figures obtained do not furnish a means of differentiating between basic and acid steels. The general conclusions arrived at are that the influence of prolonged heating on ordinary steels is to lower the elastic limit, which certainly furnishes valuable information on the brittleness due to the treatment of the metal exclusively, after deducting the natural fragility resulting from the composition of the steels themselves. The method is not yet fully developed, but the results of a number of tests made by the author at Denain, and the simplicity of the apparatus used, render it worthy of careful consideration.

H. I. Hannover [†] summarises the knowledge of the processes of deformation in tough bodies by compression, tension, and impact.

It was formerly accepted, that the resistance to compression was an inverse multiple of the resistance to tension. This is, however, not correct; the resistance to compression depends on the height of the piece of metal which is exposed to pressure. L. Bergfeld [*] gives a formula, based on the assumption of Quincke, that rigid bodies are to be considered as liquids of great tenacity, which represents the relations between the resistance to compression and the resistance to tension, and the conditions of volume of the test-piece. The tests were made with pure lead, tin, zinc, cadmium, aluminium, silver, copper, and nickel. It resulted that the resistance to tension in general increases, under increasing pressure, a small percentage of the load per unit. It is specially great for lead. With a load of 5000 kilogrammes per square centimetre it increases from about 60 kilogrammes per square centimetre to nearly six times that amount. Pressures can therefore be attained and measured without difficulty by leaden bodies, which exceed the resistance of the best steel.

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[*] *Revue de Métallurgie*, 1906, pp. 331–342.

[†] *American Machinist*, vol. xxix. pp. 189–193, 211–213.

J. Muir [†] has investigated the over-straining of steel and iron. When steel or iron are strained by tensile stresses to beyond the limit of extension, the latter is raised to a point beyond the original amount. This experiment can be repeated several times with the same specimen. After each loading the last value of the limit of extension increases again. The authors have also made experiments with compressional overstrain, and find the results to correspond to the conditions of tensile overstrain.

Resistance of Steel to Shearing.—C. Frémont [‡] discusses the resistance of structural steels to shearing stresses. He points out that fracture by shearing was formerly considered as due to slipping, and cites the experiments of Vicat in support of this contention. He then shows that this view of the phenomena does not agree with the observed facts. Fracture by shearing partakes more of the nature of a tensile stress than of a sliding stress, inasmuch as the layers compressed by the blade of the shear do not separate immediately, but remain in contact with each other, in much the same way as the portion of the test-bar which has undergone elongation as the result of a tensile stress. Reference is made to some experiments carried out on the resistance of rivets to shearing which were made in connection with the building of the Conway Bridge. The apparatus employed to ascertain the resistance is figured and described, and he points out that the results of the tests compare very closely with those obtained by tensile tests on the same material. More recently a series of experiments was carried out in connection with the material used for the construction of the Clichy Bridge near Paris. The results of shear stress were, in these instances, again closely comparable with those obtained by tensile tests on the same metal. He then criticises the conclusions arrived at by Izod in his paper read before the Institution of Mechanical Engineers. The results found by that observer differed considerably from those obtained by the author, and he attributes this difference to the method by which the experiments were carried out. Izod employed a system of double shearing (*i.e.* with two blades), whereas the author contends that tests carried out with one blade only are more accurate than those carried out with two blades. The reason for this is, that when two blades are employed, and the material sheared simultaneously from two sides, complicated compressive stresses are set up, which materially affect the result and render it widely different from that obtained where only one blade is acting. The plane of fracture of a metal which has undergone shear presents two distinct bands, one of which is brilliant and the other dull. The brilliant band is the result of the heavy friction which the surface of the metal has undergone by rubbing against the edge of the cutting blade. Where this has occurred, a series of parallel scratches are seen. The fibres of the metal which are not directly severed undergo tensile stress, and carry with them some of the broken fibres which are associated with them. These stresses last during the whole operation of shearing, and increase with the increased shearing stress. The dull band seen at the fracture of the metal reveals the structure of the metal itself, just as in the case of an ordinary tensile test-piece. The author considers that the friction of the shorn edges against the blade contribute so greatly to the resistance, as seriously to vitiate the results. In order, however, to ascertain the resistance to what he terms "pure stress," he decided to remove this disturbing factor by filing off the edges of the shorn metal, so that they could no longer remain in contact with the shorn blade. By this means such resistance as was encountered by the shears was considerably reduced, and under these conditions approximated very closely to the figures that would have been obtained on tensile tests carried out with the same metal.

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[*] *Annalen der Physik*, vol. xx. pp. 407–422.

[†] *Proceedings of the Royal Society*, vol. lxxvii. Series A. pp. 277–289.

[‡] *Revue de Métallurgie, Mémoires Originaux*, 1906, pp. 205–212.

Alternating Stresses in Iron and Steel.—T. E. Stanton * and L. Bairstow describe a series of tests of the resistance of iron and steel to direct reversals of stress. It was found that the superiority, in resistance to reversals of stress, of moderately high-carbon steels over low-carbon steels and wrought irons, which was discovered by Wöhler to exist when the rate of reversals was sixty per minute, still held good when this rate is increased to 800 per minute, although according to Reynold's and Smith's experiments, this superiority no longer exists when the rate of reversals is in the neighbourhood of 2000 per minute. As far as comparisons can be made between the results of the present experiments and those of Wöhler and Sir Benjamin Baker, there is no marked reduction in resistance due to raising the rate of reversals to 800 per minute. Experiments in which the ratio of tension to compression varied from 1·4 to 0·72, indicated that between these limits the value of the maximum range of stress was practically independent of the actual values of the limiting stresses in tension and compression. The resistance of the materials in three typical cases of rapid reduction of area of the specimens has been determined. The failure of iron specimens due to the development of the slip-lines of Ewing and Rosenhain into cracks has been determined for the case of direct stress; and the failure of moderately high-carbon steel, due to the development of cracks in the ferritic areas of the structure, has also been established.

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* *Minutes of Proceedings of the Institution of Civil Engineers*, vol. clxvi. pp. 78–134.

Impact Tests on Metals.—T. E. Stanton* describes in the research on the resistance of metals to impact now proceeding in the Engineering Department of the National Physical Laboratory. It was decided to carry out impact tests (1) to destruction by a single blow, involving a measurement of the energy absorbed in fracture, and (2) to destruction by a relatively small blow, many times repeated until fracture takes place. The first is the method most commonly adopted in impact testing, and was carried out on an Izod testing-machine. The second is one which has been recently used by Seaton and Jude. As it was considered desirable in the National Physical Laboratory tests to approach a limit of 100,000 blows for each material, a self-acting machine was indispensable, and the machine used is described in detail.

Fatigue in Steel.—W. H. Finley † describes a case of fatigue accompanied by crystallisation, which caused the breaking of a pin used in couplings of mine wagons. The fractured pin had a coarsely crystalline structure like burned steel. Annealing restored the fibrous structure, and the whole of the remaining supply of pins and couplings were therefore annealed every six months, by which means brittle pins were obviated.

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* *Report of the Executive Committee of the National Physical Laboratory*, 1905.

† *Engineering News*, vol. lv. p. 487.

The history of fatigue tests of metals is traced by E. Preuss.*

Brittleness of Mild Steel.—The annual memorandum † issued by C. E. Stromeyer, chief engineer of the Manchester Steam Users' Association, contains an inquiry into the cause of brittleness of steel plates which have come under his notice. He mentions the well-known failures of the boiler-plates of the Imperial Russian yacht *Livadia* and other cases which were never adequately explained, and he then deals with more recent failures, and mentions two boilers which had been in satisfactory use for six years and then burst, fortunately while the cold-water test was being applied, or the results would have been disastrous. The paper gives numerous analyses, more particularly of steel plates, showing segregations of impurities.

Hardness Tests.—An illustrated description of the Guillery hardness testing apparatus has appeared.‡ The principle is somewhat similar to Brinell's method, the hardness being measured by causing the ball of the testing apparatus to give an impress on the metal by the pressure given by Belleville springs under a determined deflection. The elastic limit can be ascertained by crushing a polished solid, by the Frémont method, and by the brittleness by flexion or fraction, under shock, of a notched bar.

K. Poech § subdivides steels into weld and ingot steels, and then further subdivides them into other divisions, and gives the trade names by which many of these are known. In a second table he shows commercial degrees of hardness of various types of carbon steels, and in another of alloy steels. In yet another table the steels made by the Ternitz Company are similarly dwelt with. Electro steels are also considered. The physical changes which take place when these various types of steel are hardened are next briefly dealt with, as also are the chemical changes.

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* *Baumaterialienkunde*, vol. xi. pp. 245-249.

† Memorandum by Chief Engineer, Manchester, 1906.

‡ *Engineering*, vol. lxxxi. pp. 49-50.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 362-367, with three illustrations.

P. Friesendorff* considers the Brinell sphere test for hardness from the mathematical standpoint in connection with the theory of elasticity, and concludes that it is not free from objections. Indeed, he considers that even for technical purposes some better method should be elaborated.

Collapsing Pressures of Lap-welded Tubes.—R. T. Stewart† describes results obtained in a research undertaken in order to ascertain the behaviour of modern wrought tubes when subjected to fluid collapsing pressure. It was assumed that the resistance offered by a tube to external fluid pressure would depend on the diameter, the length between transverse joints or end connections, the thickness of the walls, the deviation of the tube from perfect roundness, and the physical properties of the material employed. A hydraulic test apparatus by means of which the tests were applied, is figured and described, and diagrams given showing the collapsing pressures obtained, together with tubes showing the influence of diameter and thickness of the walls on the results. He then gives a number of formulæ by means of which the probable pressures may be ascertained for given descriptions of pipe.

Tests of High-Speed Steels.—The thesis submitted by O. Böhler for his doctor's degree described researches on high-speed tool steel, and a summary of the results is given by F. Kick.‡

Details are published by Seiler§ of experiments with high-speed drill steels. Two spiral drills of Judex-Electro steel, made by the firm of Hans Richter, Berlin, were first tested. This steel is made by an electro-fusion method from charcoal iron with the exclusion of air, and sells for about sixpence per lb. Good results were obtained, but not better than those given by other steels. Experiments with a drill made of English A. W. steel by Sadler of Stuttgart were not satisfactory, but better results were obtained with a rapid drill made of Phœnix steel by Bleckmann of Styria. These experiments consisted in drilling cast iron and tool steel until the drill ceased to act perfectly.

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* *Baumaterialienkunde*, vol. xi. pp. 122–124.

† Paper read before the American Society of Mechanical Engineers, May 2, 1906; *Iron Age*, vol. lxxvii. pp. 1472–1479.

‡ *Zeitschrift des Oesterreichischen Ingenieur- und Architekten-Vereines*, vol. lviii. p. 267.

§ *Glasers Annalen für Gewerbe und Bauwesen*, vol. lix. pp. 31–33.

Iron-Carbon Alloys.—Carl Benedicks[*] summarises the works of previous investigators concerning the equilibrium of iron and carbon alloys, and gives an account of his own experiments. The work is divided as follows: (1) Historical. (2) The hypothetical conversion at 1000° C. (mixing crystals + graphite = cementite). (*a*) The reason for adopting this hypothesis. (*b*) Is cementite exothermal or endothermal? (*c*) The reversible conversion does not exist. (*d*) Other proofs. (*e*) Necessary modifications of the diagram; the difference between the neutral system Fe + cementite and the stable system Fe + graphite. (*f*) Possible exceptions. (3) Micrographical studies. (*a*) Microstructures of solidification of the neutral system. (*b*) Microstructures of solidification of the stable system. (*c*) Microstructures of the transformation of cementite in graphite (temper carbon + ferrite). Summary. Bibliography. That cementite, carbide of iron, is endothermal and neutral, accords with the chemical determinations of Troost and Hautefeuille, and not, as Roozeboom originally accepted, exothermal, stable at low temperatures. The Roozeboom diagram must be modified by removing the line which represents the reversible reaction, mixing crystals + graphite = cementite. The two systems, the neutral system iron-cementite (steel, white pig iron) and the stable system iron-graphite (grey pig iron), must be distinguished; both must have their special curves. Very frequently in the same meltings both stable and unstable microstructures of solidification are to be found. By the aid of micrography the transformation from the neutral system, with cementite, into the stable system, with graphite, can be followed step by step. This process, which is most important in the manufacture of malleable cast iron, exactly coincides with the modified diagram. Five illustrations and thirty-one photographs accompany the paper. In the bibliography the works of forty-one authors are cited.

C. Benedicks'[†] monograph on the physical properties of carbon steel has been published in Swedish. His investigations of carbon steel deal with the electric resistance and with the magnetic properties. In the final section the various properties investigated are grouped, and a bibliography is appended.

Recent researches on alloys are summarised by L. Guillet.[‡]

W. Rübel[§] read a paper, before the Verein Deutscher Maschinen-

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[*] *Metallurgie*, vol. iii. pp. 393–395, 425–441, 466–476.

[†] *Jernkontorets Annaler*, vol. lx. pp. 1–231.

[‡] *Revue de Métallurgie*, *Mémoires Originaux*, 1906, pp. 87–98.

[§] *Glasers Annalen für Gewerbe und Bauwesen*, vol. lix. pp. 9–17, with thirty-three illustrations.

Ingenieure, on the physical properties of metallic alloys, which are prepared on the basis of pure atomic weights, at ordinary and high temperatures.

Special Steels.—L. Guillet* describes the metallurgical exhibits at the Liége Exhibition, with reference to the special steels and iron alloys shown by the Société Electrométallurgique de Froges, the Société Electrométallurgique d'Albertville, Gin, Keller, and Leleux, the Société de la Néo-Métallurgie, and the Société du Giffre. The alloys dealt with are ferro-manganese, ferro-silicon, ferro-aluminium, ferro-chromium, ferro-tungsten, ferro-molybdenum, ferro-vanadium, ferro-titanium, ferro-boron, and alloys of a more complex nature, such as ferro-nickel-silicon, nickel-chromium, nickel-tungsten, nickel-molybdenum, nickel-titanium, and quaternary alloys containing ferro-nickel, together with additional elements. In each instance, typical analyses of the alloys are given, and the physical qualities are briefly noted.

Influence of Copper on Steel.—Some experiments on the influence of copper on the properties of steel are described by G. Dillner.† The subjects dealt with comprise the occurrence of copper in steel, the influence of copper on the ductility, malleability, and weldability of steel, bending tests of copper steel, microscopic examination of copper steel, hardness tests, the solubility of copper steel in dilute acids, and magnetic and electric properties.

Experiments on the influence of copper on the properties of steel are described elsewhere by Gunnar Dillner.‡

P. Breuil § has investigated the properties of two series of steels containing copper. The first series contained 0·15 to 0·17 per cent. of carbon, and the second 0·28 to 0·41 per cent., while in both series the copper ranged from 0·0 to 32 per cent. Except in the highest percentages of copper no liquation was observed. The Brinell number increases up to a certain limit, and the steels retain their magnetic properties throughout.

The high electric conductivity of copper has, according to V. O. Pfeiffer,‖ frequently led to efforts to improve the properties of alloys of carbon and iron by the addition of this metal, and thus the question of the possibility of producing alloys of copper and iron has attracted much attention. For the purpose of the present experiments pure electrolytic copper and a Swedish nail iron containing, in percentages, carbon 0·037, silicon 0·002, manganese 0·020, phosphorus 0·035, sulphur 0·003, and slag 0·4 were employed. Two sets of tests were conducted, starting in one case with pure iron with various amounts of copper added, and, in the other, with intensely superheated molten copper, into which varying quantities of filings of pure iron were introduced. The melts took place in the electric furnace with kryptol as the resisting medium. It was easy to attain a temperature of 1700° C., using a tension of 21 volts and 300 amperes. The crucibles were formed of pure magnesia. The amounts of copper added in the first set of experiments ranged from 0·5 to 35 per cent., but in no case was any alteration in the consolidation point of the molten iron observed. The latter had, by preliminary experiment, been determined at 1530° C. On the other hand, with increasing amounts of copper present, the lowered temperature of solidification due to this metal, ranging from 1050° C. to 1060° C., became all the more apparent. The general outcome of these tests proved unmistakably that there is no evidence of any notable amount of solution of the copper in iron, and that if such should exist, the proportion of copper so taken up must be very trifling, possibly to the extent of 0·5 to 1·0 per cent., which might have escaped detection. In order to prove whether such was the case a series of experiments were carried out in which filings of pure iron were added to molten copper raised to a temperature of from 1450° to 1500° C., but even then no solution of any kind could be observed. The filings fused together on the surface of the molten metal could subsequently be separated from the mass of pure copper. It may therefore be assumed that no solid solution exists of iron in copper, while it has been shown as probable that copper is likewise incapable of solution in iron. Metallographic investigations were carried out further to elucidate the question, and a set of photomicrographic illustrations are given to explain the results obtained. These were chiefly of a negative character, as far as the production of crystals of mixed metals was concerned. It seemed possible that the presence of iron carbide, however, might facilitate the solubility of copper in iron, and therefore a special set of tests was made, using a series of iron and carbon alloys prepared for this purpose. Swedish charcoal iron of the following composition was employed (the amounts are set forth in percentages): Carbon 4·02, silicon 0·09, manganese 0·08, sulphur 0·007, and phosphorus 0·02. Here again no evidence was obtained of the existence of solid solutions, and the general outcome of the whole series of investigations renders it clear that no alloys of these metals are formed, but that the copper may, in certain circumstances, become suspended in fine particles throughout the mass. This fact renders the influence of copper on the tensile strength of iron and steel very apparent. As long as the amount of copper is small and its distribution through the iron is fairly even and uniform, it does not affect the mechanical qualities of the iron, but as soon as it exists in sufficient quantities to render an alteration possible in the structure of the mass, copper is liable to be injurious.

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* *Génie Civil*, vol. xlviii. pp. 19–22, 39–42, and 57–60.

† *Bihang till Jernkontorets Annaler*, 1906, pp. 357–378.

‡ *Kungl. Tekniska Högskolans Materialprofningsanstalt*, 1896–1906. Stockholm: Lindståhl.

§ *Comptes Rendus*, vol. cxlii. pp. 1421–1424.

‖ *Metallurgie*, vol. iii. pp. 281–287.

A descriptive series of articles on alloys is published by A. H. Sexton.*

Iron-Manganese Alloys.—M. Levin † and G. Tammann describe a series of determinations of the melting-points of manganese and of its alloys with iron. The manganese employed was obtained by the thermite process, and the iron contained only 0·07 per cent. carbon. Twenty grammes of alloy were fused in a porcelain crucible in an electric carbon-tube furnace, and the temperatures measured by a thermo-couple specially protected by means of a layer of magnesia. The melting-point of manganese was found to be 1247° C. In the alloys the beginning and end of crystallisation were observed, the curve plotted giving the melting-points and duration of crystallisation only. This curve is a smooth one, and the authors conclude that iron and manganese form an unbroken series of mixed crystals. The microstructure of the ingots when cooled in the ordinary way does not appear to bear out this conclusion, since two sharply-defined constituents appear in the sections, but the authors attribute this to the rapid rate of cooling, which did not allow of the establishment of equilibrium between the crystals and their mother-liquor during solidification. An ingot which was cooled much more slowly showed a closer approach to homogeneous structure. The effects of manganese on the transformation temperatures of iron were not investigated, and the magnetic properties of the manganese steels produced were only superficially examined by means of an indicating magnetic needle.

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* *Mechanical Engineer*, vol. xvii. pp. 123, 181, 242, 259, 274, 346, 445, 535, 548, 607, 695, 716, 869.

† *Zeitschrift für anorganische Chemie*, vol. xlvii. pp. 136–144.

The progress of the manufacture of ferro-manganese in France is described.* The method advocated is to produce ferro-manganese in the blast-furnace, and subsequently to refine it in the electric furnace. The process is being carried out by the Société des Acieries, Paris and Outreau.

Iron-Nickel Alloys.—The seventh report on researches on iron-nickel alloys by M. Rudeloff has been published.† The experiments relate to iron-nickel-carbon-manganese alloys, the influence on the mechanical properties being shown in diagrams. He finds that in a cast condition the graphite-free alloys, with 0·5 to 0·6 per cent. of manganese and 0·12 to 0·16 per cent. of carbon, as well as with 0·20 to 0·30 per cent., show the greatest tensile strength and the lowest elongation at about 16 per cent. of nickel. On the other hand the graphite-free alloys, with 4·5 to 5 per cent. of manganese and 0·5 to 1 per cent. of carbon, show the lowest tensile strength and the greatest elongation at 16 per cent. of nickel; with 30 per cent. of nickel the tensile strength is again higher, and the elongation lower. With material nearly free from nickel (0·08 per cent. of nickel) with about 1 per cent. of carbon, the tensile strength of the cast, and also of the rolled material, increases with increasing percentages of manganese, whilst the elongation decreases. With 4·5 per cent. of manganese the rolled bars become too hard to be worked. With material with 3 per cent. of nickel the tensile strength increases, and the elongation decreases. The higher the proportion of carbon, the more distinct is the influence of the increasing proportion of manganese. It is noteworthy that material with 8 to 16 per cent. of nickel and less than 2 per cent. of manganese experiences considerable increase of the tensile strength after heating and slowly cooling, whilst quick cooling has no effect.

E. Dixon ‡ describes some extensive experiments recently carried out by Thomas Firth & Sons, Limited, of Sheffield, on nickel steel. The principal advantages of such steel as compared with carbon steels for reciprocating and revolving parts of engines are: Higher limit of elasticity, higher ultimate tensile strength, and higher resisting power against shock or fatigue stresses. From the results obtained, on an acid open-hearth steel it was found that the presence of 4·75 per cent. of nickel in the steel makes the elastic limit equal to the ultimate tensile strength of the carbon steel, without materially reducing the percentage of elongation. Whilst for a carbon steel to have an ultimate tensile strength of 48 to 50 tons the elastic limit would not be more than 24 to 26 tons, and elongation in 2 inches only 18 to 20 per cent., not only are the results of tests in the low-carbon nickel steel greatly superior to the high carbon steel, but there is an entire absence of brittleness, which is so frequently and painfully evident in the latter. These facts are of first importance in the highest development of petrol engines, it being clearly shown that by the use of nickel steel a material reduction in weight may be effected, and at the same time an increased strength attained. Tables are given showing the results of longitudinal tests obtained from various percentages of nickel and carbon steels, while with the view of obtaining a correct comparative series of results, the specimens were selected from steels as similar in chemical analysis as possible, except for the presence of nickel in certain samples. The results clearly demonstrated the distinct advantage of nickel steel as compared with carbon steels in the oil-tempered state, the resisting power against shock or fatigue stresses of nickel steels as compared with carbon steels being plainly shown. In addition to the very high ratio of elastic limit to the breaking strain, together with the abnormal elongation, a steel annealed at 1175° F., and left to cool in the furnace, also displays very great superiority over carbon and nickel steels when submitted to shock and fatigue stresses, and was in a perfect condition for high-speed engine construction.

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* *Génie Civil*, vol. xlviii. p. 243.

† *Verhandlungen des Vereins zur Beförderung des Gewerbfleisses*, 1906, pp. 1–68, with fifty-one illustrations. This has been reprinted in pamphlet form.

‡ *Engineering*, vol. lxxxii. pp. 22–23.

Vanadium as a Steel-making Element.—J. Kent Smith[*] describes his investigations on the properties of vanadium steels. The effect of different quantities of vanadium on the static qualities of steels, with varying amounts of carbon and constant proportions of the other ingredients, led to the conclusion that the introduction of this element would give better results with quaternary than with ternary steels. The comparative effects of chromium and vanadium on the static tests—elastic limit, ultimate tensile strength, elongation and reduction of area—showed that the latter element gave better results than the former, and that the most favourable numbers were obtained with steels containing both these metals. Vanadium seems to retard the segregation of carbides.

[*] *Journal of the Society of Chemical Industry*, vol. xxv. pp. 291-295.

Testing-Machines.—J. Hartley Wicksteed[*] describes the first testing-machine made in South Wales in 1829, and a 350-ton horizontal machine made in 1906, showing the most recent developments. The latter machine was installed at Lloyd's Bute Proving House, Cardiff, for the purpose of testing the largest anchors used in the British Navy or the mercantile marine, with the statutory proof-load, and for ascertaining the breaking-load of the largest cables now used. Recently a wrought-iron stockless anchor weighing 61 cwts. 1 qr. was tested to 49 tons on this machine. Three iron links of the 3¾-inch diameter cable for the Cunard express steamship *Mauretania* were also tested on this machine. The proof-strain of the cable was 189·8 tons, and the breaking-strain 265·7 tons. The three links elongated 2·42 inches at 265·7 tons, and 5·7 inches at 350 tons. The machine stood the sudden breaks with comparatively small vibrations. A similar sample of chain stood 370 tons without showing any signs of defect.

An illustrated description has been published by T. E. Stanton[†] of the repeated-impact-testing machine at the National Physical Laboratory.

A. Martens[‡] describes some of the instruments designed by him for the Kgl. Materialprüfungsamt at Gross-Lichterfelde-West. The first is an instrument to measure hardness. Hardness is the resistance which one body opposes to the impression of another body. Hardness is either determined by the scratching method, by which the body which is pressed against the body to be tested changes its relative position, or by the impression method, in which the two bodies remain at rest during the experiment. For the first method the Martens tester for hardness by scratching is constructed; as measure of hardness a loaded diamond with a sharp point is employed. The measure of hardness is the load required to make a scratch one-hundredth of a millimetre wide. The impression method has been specially developed by Brinell. A hard steel ball is pressed into the surface of the body of which the hardness is to be determined, so that a lasting impression is obtained. The specific load caused by a definite pressure is used by Brinell as a measure of hardness. Martens employs the depth of the impression as measure of the hardness. A description of the apparatus constructed on these lines, and also of a recording apparatus with the aid of drawings, is given. The Martens apparatus for the rapid determination of the change of volume or contraction of cement and similar substances is also described.

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[*] *Proceedings of the Institution of Mechanical Engineers*, July 30, 1906.

[†] *Engineering*, vol. lxxxii. pp. 33–35.

[‡] *Verhandlungen des Vereins zur Beförderung des Gewerbfleisses*, 1906, p. 71.

A machine, designed at the Prague Bridge Works, for bending tests of cast iron is described and illustrated by Robert Schönhöfer.*

J. W. Bramwell † discusses the allowable unit loads on knife edges for testing-machines.

The impact testing-machine at Purdue University is described by W. K. Hatt ‡ and W. P. Turner. It works with falling weights of 23, 45, and 115 kilogrammes, with a fall of 1·95 metres, and will receive test-pieces 1·8 metres long.

An illustrated description has appeared § of a vertical testing-machine of 600,000 pounds capacity, made by Riehlé Brothers of Philadelphia. The equipment comprises hardened steel plates for taking the thrust of compression specimens. The extreme height of the machine is 36 feet 8 inches, its length 17 feet, and its weight 100,000 pounds.

An illustrated description has been published ‖ of a remarkable testing-machine of 270 tons constructed for the University of Illinois. It is 11 metres high, and will test for compression pieces 7½ metres long, and for tension pieces 6·6 metres long, provided that the elongation does not exceed 20 per cent.

A description is given ¶ of the Board of Trade Electrical Standards Laboratory in Whitehall. It contains the government standard ohm, ampere, and volt instruments. The work of the laboratory falls into two categories—verification, or the comparison of other instruments with the legal standards; and approval, which consists of examining and testing such instruments as the Board is authorised to deal with.

Strength of Materials.—F. P. McKibben ** gives the results of tests made with twenty-seven specimens of rolled steel angles at the Massachusetts Institute of Technology.

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* *Zeitschrift des Oesterreichischen Ingenieur- und Architekten-Vereines*, vol. lviii. pp. 375–376.

† *Engineering News*, vol. lv. p. 652.

‡ *Railway and Engineering Review*, June 30, 1906.

§ *Engineering*, vol. lxxxi. pp. 208–209.

‖ *Bulletin de la Société d'Encouragement pour l'industrie nationale*, vol. cviii. pp. 463–466.

¶ *Engineering*, vol. lxxxi. pp. 683-686.

** *Engineering News*, vol. lvi. pp. 14–15.

The testing and inspection of railway supplies in the United States is described by R. Job.*

Steel or Iron as Structural Material.—G. L. Gérard † calculates the resistance of steel frame structures to wind pressure, and gives formulæ for ascertaining the stresses set up, and the margin of strength required in such structures.

Details are given by H. Kralupper ‡ of the report of a committee appointed by the Austrian Association of Engineers and Architects, to consider the tests to be required of material to be used in bridge construction. Special attention was directed to the question as to whether basic metal was equally as good as acid open-hearth material for the purpose, and over 2000 separate tests have been made with a view to determine this. The basic metal was shown not to be in all respects equally satisfactory as that made in the acid-lined furnace. Direct comparison was made between basic metal made at the Kladno Works, and that produced in acid-lined furnaces at Witkowitz, where a combined Bessemer open-hearth method is in use. The finished metal contained :—

	Basic. Per Cent.	Acid. Per Cent.
Average phosphorus	0·065	0·035
Maximum phosphorus	0·110	0·066
Average sulphur	0·050	0·029
Maximum sulphur	0·086	0·046

Soft metals such as these are peculiarly subject to liquation. They are therefore most liable to changes in quality due to this cause. The acid metal was found to contain about 0·14 per cent. of copper, as compared with 0·01 per cent. in the basic metal. It is contended that all samples should be taken at the source of origin owing to the errors that might otherwise result from liquation changes. The committee, in its report, after describing the methods adopted and the results attained, submits proposals as to the tests that should be made. Full tensile tests and ball-compression tests for hardness are recommended, together with bending tests; others for red-shortness ; etching to determine texture ; all charges are to be separately examined; samples are to be taken from the metal with as large a section as possible. To determine the lowest strength of the metal in a charge, a test-bar should be cut off the edge of a thicker piece that has been rolled hot. In examining the surface character of the rolled metal the inner surfaces at the angles should receive special attention. Seventy-three figures and thirty-two tables accompany the report.

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* *Journal of the Franklin Institute*, vol. clxii. pp. 31-36.

† *Revue Universelle des Mines*, vol. xv. pp. 133-205.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 380-384.

T. Cooper * gives details of some of the special precautions that had to be observed in the eye-bars required for the Quebec Bridge. The bars forming the tension members were 15 inches wide, 50 to 58 feet long, and $1\frac{1}{4}$ to $2\frac{1}{16}$ inches thick, the pins being in some cases 12 inches in diameter, and 8 feet to 10 feet long. Owing to the tensional stresses to which the eye-bars were exposed, it was found inexpedient to use soft or ductile metal, and steel of high tensile strength was employed, the eyes being stretched longitudinally cold before finally boring to exact length.

Details of the result of the investigation of the failure of the steel tie-rod which caused the collapse of the roof of the Charing Cross terminus in January last have been published.† The report contains diagrams and a photograph after fracture of the section of the bar which escaped oxidation. The evidence of P. C. Tempest was to the effect that the weight of staging carried by the principal at the time of its collapse amounted, approximately, to five pounds per square foot of roof area. The factor of safety in the tie-bar which broke, assuming an ultimate strength in tension of 20 tons per square inch, was therefore 3·89, and considerably heavier weights in the shape of staging had been placed on the roof thirty-seven years before, on the occasion of a fire on the station platform. He described the nature of the supervision carried out, and advanced the theory that the broken tie-rod had been imperfectly welded, as shown by a bad flaw at the point of fracture. The fractured section revealed the fact that only a small proportion of the area of the metal of the bar had been doing its work, there being little more than one-third available for this purpose. The weld was in no way affected by rust or corrosion. W. G. Kirkaldy, who had examined the bright fracture, was also of opinion that the cause of the failure was a defective weld, there being a trace of cinder in the very centre of the fracture. On treating the portion of the bar with acid, the original method of manufacture could be ascertained, and it was found that there had been eight slabs of iron piled one on top of the other. There had been a disturbance in the layers of iron composing the bar. Sir Benjamin Baker confirmed the view,

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* *Proceedings of the American Society of Civil Engineers*, vol. xxxii. pp. 14–31.

† "Report of the Failure of the Charing Cross Roof, South-Eastern and Chatham Railway," by Major J. W. Pringle, R.E.; *Engineer*, vol. ci. pp. 636–638.

and the report concludes with a series of observations designed to prevent future accidents of a similar nature. It is pointed out: (1) That in old iron roofs of similar design, more especially where welded bars of any size have been used, there is danger to be guarded against of concealed flaws, which may grow in size under continued tensional stress, although in itself that stress may not be exceptional. (2) That unless additional security be afforded by the duplication or strengthening of the main tensional members, there is possible risk of failure. (3) That where such risk of failure exists, it is necessary to consider whether the walls supporting the roof are in themselves sufficiently strong to resist the thrust which such failure will bring on them, and, if not, to strengthen them.

Other reviews of the report of Major J. W. Pringle on the fall of the roof of Charing Cross Station and its causes have been published.*

A standard specification† for structural steel for bridges has been drawn up by the Engineering Standards Committee. This specification has been drawn up by an influential sectional committee, with Sir Benjamin Baker as chairman, and modifications introduced by the Royal Institute of British Architects have been adopted.

Fire-box Steel Failures.—M. H. Wickhorst ‡ deals with fire-box steel failures. The harder grades do not stand overheating and sudden changes of temperature satisfactorily; but it is doubtful if high sulphur is the cause of failures. 0·035 per cent. is quite sufficiently low for fire-box steel.

Strength of Rivets.—E. Simonot § discusses the strength of rivets which have been heated and placed in position while hot. He shows that such rivets cool with greater or less rapidity, in proportion to the mass of metal with which they are in contact. Tables showing the behaviour of ordinary steel rivets and of rivets made from nickel steel are given. The static resistance to fracture of rivets which have been riveted in their heated condition is, he concludes, greater than that of the original bar from which they have been made. At the same time, this resistance varies considerably with the temperature of the rivet.

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* *Iron and Coal Trades Review*, vol. lxxii. pp. 2225–2226; *Architect*, June 22, 1906.

† "British Standard Specification for Structural Steel for Bridges and General Building Construction," 2s. 6d. net, 1906. (London: Crosby Lockwood & Son.)

‡ *Iron Age*, vol. lxxvii. p. 2059.

§ *Génie Civil*, vol. xlviii. pp. 378–379.

Fire Prevention.—A report has been issued * of fire tests made on a set of two steel roller shutter doors and a single steel roller shutter door. The duration of the test was, with the two doors, four hours, and the maximum temperature attained was 1800° F.; while in the second series of tests the fire was maintained for $2\frac{1}{2}$ hours, the same temperature being reached. The doors, which were of the "Kinnear" pattern, withstood both series of tests well.

Wire Ropes.—The constantly increasing depths of mine shafts necessitate the use of longer winding ropes, and as the maximum length of wire that it is possible to draw is limited by the mode of manufacture, wires have often to be joined by brazing. Tests made by H. Louis † to determine whether it is possible to produce a brazed joint equal in strength to the original wire, suggest that (1) a braze should have a length of at least six diameters; (2) a good electric weld is a little, but only a little, weaker than such a braze; (3) it is very desirable that the joined portion of the wire should undergo the process of hardening and toughening known as "patenting," after brazing or welding; and (4) the joints in the wires composing a rope should be spaced some considerable distance apart.

Von Hirschland ‡ gives a full description of the manner in which bending tests were carried out. The stiffness of the rope, that is the difference between the forces at each end of a rope pulled over a pulley, and the work of bending, which is the work required to bend and afterwards straighten a rope pulled over a pulley, according to experiments made by the author, differ considerably from the figures given by Weisbach, Redtenbacher, and Grashof. The author gives a new formula, based on the results of his experiments for wire ropes, from 10 to 14 millimetres, and complete tables and diagrams.

Specifications.—Sir John Wolfe Barry, § in dealing with standardisation in British engineering practice, gives an account of the work which has been carried out by the Engineering Standards Committee since its first institution in 1901. There are now 36 sub-committees, with 260 members, dealing with 30 different branches of the work.

The Engineering Standards Committee has made arrangements with a firm at Bilston to manufacture commercial sets of standard pipe-flange templates in large quantities. The templates are made, with extreme accuracy, of thin steel plate painted over with aluminium paint, a small piece being cut out at the extremity of each centre line so as to enable the fitter to see that the centre line of the template coincides with the centre line of his flange. The existence of these templates should enable full advantage to be taken of the standardisation that the committee has sought to effect.

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* *Official Report of the British Fire Prevention Committee, Red Book*, No. 111.

† *Transactions of the Institution of Mining Engineers*, vol. xxxi. pp. 443–450.

‡ *Dinglers Polytechnisches Journal*, 1906, pp. 264, 279.

§ Paper read before the British Association, August 1906.

The standardisation of error is a difficult problem to which the attention of the Engineering Standards Committee has been directed. Much has been written on the limits of error, but no attempt has hitherto been made to deal with the subject in the exhaustive manner that it is treated in reports No. 25 (London: Crosby Lockwood & Son, price 10s. 6d. net) and No. 27 (price 2s. 6d. net), issued by sectional committees of the Engineering Standards Committee. Report No. 25 deals with errors in workmanship, based on measurements carried out for the committee by the National Physical Laboratory. In order to assist them in the formulation of a system for limit gauges, the committee, in addition to collecting evidence from both manufacturers and users, carried out a comprehensive series of measurements on actual work, and a record of these measurements is contained in report No. 25, but no system of limits is laid down therein, the recommendations being contained in report No. 27, which deals with British standard systems for limit gauges (running fits). The measurements were carried out on a number of plain cylindrical shafts and holes from 2 inches to 12 inches in diameter. The recommendations based on these measurements deal with running fits, and cover diameters of ¼ inch up to 12 inches. It is proposed that the allowance for a running fit shall be made in the hole, and not on the shaft. The standard tolerances and allowances are clearly shown graphically and in tabular form. Four grades of work are provided for, the highest being intended for special cases in which extreme accuracy is necessary.

The Engineering Standards Committee has also issued standard specifications for material used in the construction of railway rolling stock.* Covering 62 folio pages, this is one of the most important of the reports issued by the Engineering Standards Committee, dealing, as it does, with nineteen specifications for tires, axles, springs (laminated, volute, and helical), copper plates, copper rods, copper and brass tubes, steel forgings, blooms, castings, steel for locomotive boiler and frame plates, and steel for carriage and waggon underframes. In many cases where a chemical analysis is included, a duplicate specification containing no analysis clause has also been provided for the purpose of enabling the standard specifications to be used by those engineers whose practice it is not to specify any chemical requirements.

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* "British Standard Specifications for Material used in the Construction of Railway Rolling Stock," 1906, 10s. 6d. net. (London: Crosby Lockwood & Son.)

Standard specifications have also been drawn up for nuts, boltheads, and spanners,* and for steel conduits for electrical wiring.†

Steel Rails.—G. Moyle ‡ discusses the phenomenon known as roaring rails, and gives a comprehensive list of the explanations which have from time to time been put forward as to the cause of the corrugations to which roaring is due. None of the alleged causes can be considered as satisfactorily accounting for the formation of the corrugations, which seem to occur more commonly on rails in India than elsewhere. The reversal of these rails is found to be attended with danger of breakage, as is likewise the shifting of chairs or sleepers.

Tests of Armour-Plate.—W. E. Edwards § deals with the resistance of armour-plate to attack by projectiles. He describes the improvements made in manufacture. Krupp plates, although not, perhaps, harder in the face than Harveyed plates, are very much tougher in the back. Nickel steel was first introduced by Schneider in 1889, and in 1891 or 1892 the St. Chamond Works employed a nickel steel to which was added a small percentage of chromium. Nickel steel combines great tensile strength and hardness with a high elastic limit and great ductility. This combination of tensile strength, hardness, and ductility gives it especial value for armour. Chromium, which is now invariably used in Krupp armour, adds still further to the hardness and toughness of the plate. The composition varies slightly among different makers, but a typical analysis will show a composition of 3·5 per cent. of nickel, 1·5 per cent. of chromium, 0·3 per cent. of carbon, 0·7 per cent. of manganese, and 94 per cent. of iron. The heat treatment of nickel chromium armour-plates is very long and complicated. The range of temperature at each of the various operations is very limited, and great care has to be taken to prevent the limits being passed. The value of cementing is at a maximum for plates of about 6 inches in thickness, the figure of merit, which in exceptional cases may be as much as 3, falling off both above and below this point. The reason is doubtless to be found in the fact that the maximum depth to which the carbon enters is about 2 inches. In a 6-inch plate this gives the best relation of hard face to tough back. Above this the plate lacks a sufficient proportionate depth of face, and below 6 inches the plate tends to be brittle where the full carburisation is given, or if the two to one proportion be maintained, the hard face is not deep enough to exercise its full value in breaking up the projectile. Within certain limits, the resisting power of hard-faced plates is much reduced when armour-piercing projectiles used in the attack are capped. A stout rigid backing assists a plate very much more, however, against this class of attack than against the perforating attack of a capped shot. Occasionally a capped projectile punches out a more or less cylindrical plug of about its own diameter from a plate. In such cases it will usually be found that the projectile has been broken up. This peculiarity can best be accounted for either by attributing abnormal excellence to the plate or to that portion of it concerned, for plates sometimes vary considerably and are not of uniform hardness throughout. Under favourable conditions the perforating power of a projectile is increased about 20 per cent. by the cap, an advantage which is not, however, maintained below a certain velocity. The angle of incidence must, as a general rule, fall within 30 degrees to the normal for any advantage to be given by the cap.

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* "Report on British Standard Nuts, Bolt-heads, and Spanners," No. 28, 1906, 2s. 6d. net. (London: Crosby Lockwood & Son.)

† "British Standard Specification for Steel Conduits for Electrical Wiring," No. 31, 1906, 2s. 6d. net. (London: Crosby Lockwood & Son.)

‡ *Iron and Coal Trades Review*, vol. lxxii. pp. 2310–2311.

§ *Engineer*, vol. cii. pp. 252–254.

CHEMICAL PROPERTIES.

Spectrum of Iron.—Photographs of the arc spectrum of iron under high pressures have been dealt with by W. G. Duffield.* The apparatus by which the pressures were obtained was designed with the help of Petavel. The photographs demonstrated clearly that several lines not merely widen out, but undergo an actual shifting towards the red.

Passivity of Iron.—C. McC. Gordon † and F. E. Clark discuss the electrode capacity of iron and its bearing upon passivity.

Chemistry of Iron.—A lecture on the chemistry of iron, by Baron H. von Jüptner, ‡ has been delivered before the German Chemical Society.

Iron Carbonyl.—Sir J. Dewar § and H. O. Jones describe the properties of iron carbonyl. It is a yellow liquid with the formula $Fe(CO)_5$, and boils at 102·8° C. At 0° C. it has a specific gravity of 1·4937, and at 60° C. the specific gravity is 1·3825. On exposure to light it decomposes into carbon monoxide, and a solid substance having the formula $Fe_2(CO)_7$.

Susceptibility of Iron in Colloidal Solution.—E. F. Burton ‖ and P. Phillips give an account of experiments made to determine the susceptibility of a colloidal solution of iron in methyl alcohol. The susceptibility found indicates that iron in colloidal solution has much stronger magnetic properties than it would have if it existed merely as a ferric salt in the solution; on the other hand, the magnetic properties are weaker than those of pure iron. The results seem to point to the conclusion that each particle in the colloidal solution consists of a core of pure iron surrounded by a layer of some compound of iron. It is suggested that this compound may be the hydroxide.

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* Paper read before the British Association, August 1906.

† *Chemiker Zeitung*, vol. xxx. p. 910.

‡ *Berichte*, vol. xxxix. pp. 2376–2402.

§ *Proceedings of the Royal Society*, vol. lxxvi., Series A, pp. 558–577.

‖ *Proceedings of the Cambridge Philosophical Society*, vol. xiii. pp. 260–268.

Electrolytic Deposition of Iron.—A. Ryss [*] and A. Bogomolny have investigated the conditions favouring the electrolytic deposition of thick deposits of iron from aqueous solutions of ferrous chloride and sulphate. A current density of 0·3 ampere, in a solution containing 200 grammes of the crystallised salts per litre of water, and the addition of 50 grammes of magnesium sulphate, and 5 grammes of sodium bicarbonate, yield the most satisfactory results.

Separation of Graphite from Cast Iron.—According to F. Wüst,[†] a pure cast iron, containing 3·96 per cent. of carbon was melted, and weighed quantities of a foreign element added. After casting, care being taken to ensure uniformity of conditions, the alloy was analysed. The ratio of graphite to total carbon was then plotted against the percentage of added foreign element. The presence of tin reduces the solubility of carbon in pure iron, and therefore increases the separation of graphite. The separation of graphite due to silicon is not affected by the addition of tin. In the presence of an excess of carbon, iron can dissolve a maximum of 16 per cent. of tin. The addition of sulphur reduces the solubility of carbon in iron, but does not cause the conversion of combined carbon into graphite. The effect of silicon in causing graphite to separate is neutralised by the addition of sulphur. Phosphorus is without influence on the carbon in silicon-free iron as long as the proportion of phosphorus does not exceed 2·5 per cent.; larger quantities produce a proportional separation of graphite. In the presence of 0·9 per cent. of silicon, 3 per cent. of phosphorus and upwards causes separation of graphite.

Influence of Nitrogen on Iron and Steel.—A. Pourcel [‡] criticises the conclusions of H. Braune and H. Tholander on the influence of nitrogen on the properties of iron and steel. The first-named observer stated the influence of nitrogen on three steels: a hard steel containing 1·15 per cent. of carbon; a semi-soft steel containing 0·5 per cent.; and a soft steel containing 0·20 per cent.; and on a dead soft iron containing 0·06 per cent.—all four samples containing traces only of sulphur and phosphorus. He showed that the tensile strength increased with the percentage of nitrogen, while the elongation diminished. In the case of hard steel, when the percentage of nitrogen exceeded 0·03 this change occurred suddenly, and the metal became exceedingly brittle. In the steel containing 0·5 per cent. of carbon, the critical percentage of nitrogen, *i.e.* the percentage which corresponded with the sudden drop in the malleability of the steel, was between 0·04 and 0·05 per cent. of nitrogen, a proportion which increased to 0·065 per cent. in the case of a soft steel, and 0·08 per cent. in that of the dead-soft iron. Nitrogen thus appears to have an influence similar to that of phosphorus, and Braune seeks to attribute the cause to those hitherto inexplicable differences in behaviour between steels of otherwise similar composition to the presence of nitrogen. His experiments confirm the fact that nitrogen does not combine directly with iron, but only does so by the medium of a basic slag and a reducing atmosphere. In these circumstances the combination of nitrogen has a direct relation to the formation of cyanides in the furnace. Indeed blast-furnaces producing any considerable proportion of potassium-cyanide yield pig iron of inferior quality. Braune considered that the actual combination of nitrogen with iron might take place in the blast-furnace or in the converter, but the author fails to see how, in view of the fact that the atmosphere in the converter is an oxidising one, this contention can be supported. Therefore he considers that if the cyanides aid the absorption of nitrogen by the reduced but still solid iron, it would still be doubtful whether, on fusing such iron, the nitrogen would continue to be retained, unless some constituent were present that had the effect of keeping it in combination. Reasons exist, in his opinion, for suspecting that the presence of titanium affords an explanation of this action, and he quotes such authorities as Caron, Frémy, Berthier, and Deville in support of his views. Caron, indeed, pointed out that when a sample of iron was made to absorb nitrogen by being submitted to the action of a current of ammonia when red hot, the combined nitrogen disappeared if the iron were subsequently melted. Tholander considers that in the Bessemer process the nitrogen bubbles through a path of molten metal, whereas in the open-hearth furnace it only impinges on the surface of the slags with which the bath of metal is covered. It would be inferred, therefore, that steel produced in a converter would contain more nitrogen than open-hearth steel, and that this would afford an explanation of the superior quality of the steel obtained by the latter process. The author points out that while this might be one of the causes, it assumes that the nitrogen of the air may combine directly with iron, which is contrary to the observations of Braune and of Caron. Wijkander states that the quality of the steel is less good when it has undergone a prolonged treatment either in the converter or in the open-hearth furnace, which is, he considers, due to a certain degree to over-oxidisation. Tholander, however, contends that over-oxidation which will not yield to an addition of ferro-manganese is improbable, and that, on the contrary, the impaired quality of the metal may be attributed to absorption by nitrogen. In practice, however, the opinions of Wijkander are borne out, as it is seldom found possible to restore the quality of the metal by additions of ferro-manganese. It is interesting to recall the results published in 1880 by Allen on the nitrogen in steel derived from various sources. It is pointed out, on the other hand, that a blow unduly prolonged results in the production of an abnormal quantity of peroxide of iron, and that this attacks the refractory linings, which, containing large proportions of clay, may be regarded as a source of titanium, it being well known that all the clays contain a certain proportion of that element. Nevertheless, as it can hardly be supposed that it is the presence of a nitrate of titanium which diminishes the malleability of the over-blown metal, it might be that the explanation could be found in the oxide of iron which becomes disseminated through the mass of the metal and renders it lacking in homogeneity. According to Tholander the metal obtained in the basic open-hearth furnace may absorb a higher proportion of nitrogen than that made on an acid lining, because the basic slag may lead to the formation of calcium, manganese, and iron cyanides, which act as carriers for the nitrogen. The conditions shown above as favouring the absorption of nitrogen, namely a reducing atmosphere and a basic slag, are thus, he considers, fulfilled. The author combats this view, for, while he allows that a dephosphorising slag is certainly basic, he will not admit that the atmosphere is a reducing one. The results obtained by different observers do not appear to agree, while in view of the undoubted influence which nitrogen has on the property of steel, he considers that it should form the subject of careful investigation by metallurgists. With regard to the influence of admixed oxide and slag in injuring the properties of steel, he points out that such admixtures can be removed if the metal be subsequently heated in an electric furnace.

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[*] *Zeitschrift für Elektrochemie*, vol. xii. pp. 697–703.
[†] *Metallurgie*, vol. iii. pp. 169–175, 201–205.
[‡] *Revue Universelle des Mines*, vol. xv. pp. 229–236.

Chromium Steel.—The relative merits of low carbon and high carbon ferro-chromium in the manufacture of chromium steel are discussed.* The question of the carbon content in the ferro-chromium used is of far greater importance to the steel manufacturer than is generally understood. In the investigation of the causes of failure of certain steels, it has been shown that it may be traceable to the ferro-chromium used in the manufacture of these steels. The carbon present in all ferro-chromium exists to a large extent as a carbide of chromium. This carbide of chromium does not all completely dissolve or alloy itself with the steel in which the ferro-chrome is used, but a portion remains in the form of crystals of carbide of chromium, causing flaws and defects in the resulting steel. In the case of armour-piercing projectiles, it has been found that in a great many instances the projectiles break, and that the breaking is due to these crystals having caused flaws in the steel. In order to establish these points, steel was prepared by using the ordinary high carbon ferro-chrome, containing various percentages of carbon, from 2 per cent. up to 9 per cent., or 10 per cent., and also from the well-known refined ferro-chrome, containing 0·5 per cent. to 1 per cent. carbon, and usually averaging about 0·6 per cent., and it was found that the steel made from the low carbon or refined ferro-chrome was perfect in every respect, and there was no trouble with it, as was the case with the steel made from the higher carbon alloy.

Iron and Molybdenum.—E. Vigouroux † has obtained definite compounds of iron and molybdenum by reducing mixtures of the two oxides by the Goldschmidt method, and also by heating mixtures of the finely-divided metals at high temperatures in a stream of hydrogen. He succeeded in preparing synthetically four well-defined ferro-molybdenums, having the following formulæ: Fe_2Mo, Fe_3Mo_2,

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* *Iron and Coal Trades Review*, vol. lxxiii. p. 1263.

† *Comptes Rendus*, vol. cxlii. pp. 889–891, 928–930.

FeMo, and $FeMo_2$, and describes their method and preparation, and their properties. They were obtained by the direct fusion of pure iron and molybdenum in a magnesium boat placed in an atmosphere of hydrogen, and also by the use of thermite in magnesia crucibles acting on a powdered mixture of aluminium, oxide of iron, and pure molybdenum. The alloys were homogeneous, and displayed magnetic properties. They were greyish and granulated, and were very hard and brittle, characters which were more accentuated the higher the proportion of molybdenum.

Compounds of Iron with Silicon.—In the interior of the siliceous mass obtained from an electric furnace, in which coke, sand, and lime were heated together at a temperature of about 3000° C., B. L. Vanzetti * found metallic buttons having the specific gravity 5·76 to 6·29, a hardness of about 7 on Mohs' scale, and the composition FeSi. The chemical characters of the substance point to its being a chemical individual, as also does the absence of magnetic properties. The iron, which occurs to the extent of 3 per cent. of ferric oxide in the coke, doubtless combines firstly with carbon, the latter being subsequently displaced by silicon, formed by reduction of the silica present. Similar experiments, at a higher temperature than 3000° C., yielded masses varying in appearance and specific gravity from 3·96 to 5·54, and more readily acted on by reagents than FeSi. One of the buttons had a specific gravity approximately equal to that of $FeSi_2$, but its composition did not correspond with that formula.

Ferro-Tungsten.—E. Vigouroux † has prepared a series of pure ferro-tungstens, by the alumino-thermal process. They were obtained in magnesia crucibles from pure ammonium tungstate by calcining and reducing in hydrogen at a temperature of about 400° C. Three alloys were made, the chemical composition and behaviour of which were studied.

The Rusting of Iron.—It is known that ammonium chloride solution acclerates the rusting of iron. J. T. Nance ‡ finds that interaction takes place with evolution of hydrogen and liberation of ammonia; iron passes into solution in the ferrous state, and is not precipitated in the absence of air, owing to the excess of ammonium chloride present. The solubility of iron in solutions of different concentration does not diminish proportionally with the amount of ammonium chloride present; hence it is probably due to the action of hydrogen ions, formed by hydrolysis of the salt, as similar proportional numbers are found for the solubility of iron, and for the catalytic effect of the solutions on the hydrolysis of methyl acetate. The rate of rusting of iron in these solutions varies with the concentration in a similar manner, leading to the conclusion that rusting is due to the (mainly catalytic) action of hydrogen ions. In support of this, it is found that the chlorides of weak bases accelerate rusting far more than do those of the strong bases.

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* *Gazzetta de la Societa Chemica*, vol. xxxvi. pp. 498–513.

† *Comptes Rendus*, vol. cxlii. pp. 1197–1199.

‡ *Proceedings of the Chemical Society*, vol. xxii. pp. 143–144.

Corrosion of Iron and Steel.—At the ninth annual meeting of the American Society for Testing Materials, held on June 21 and 23, at Atlantic City, New Jersey, a number of papers were read * on the subject of the relative corrosion of steel and iron. The corrosion of structural steel, as affected by its chemical structure, was dealt with by J. P. Snow, while M. Toch presented a report of experiments on the electrolytic corrosion of structural steel. In the discussion which followed, H. M. Howe † pointed out that steel has come into wide use simultaneously with a great increase in the sulphurous acid in city air, and of strong electric currents in city ground, conditions which would further corrosion. On the one hand, popular belief supports the contention that steel corrodes faster than wrought iron, while experiments tend to show that while under some conditions this is so, under others the reverse is the case. He recognises three prominent differences between iron and steel, which ought to cause a difference in their rapidity of rusting—first, blow-holes; second, manganese; and third, the presence of cementite in steel, and of cinder in wrought iron. He does not consider that manganese has been proved to be a serious cause of rusting. The part played by cinder may, in the case of wrought iron, be protective. Causes may conduce to reverse the initial relative rapidity of the rusting of steel and iron. Steel, which in the first few months may rust faster than wrought iron, may, on greatly prolonging the experiments, actually rust more slowly. Speller referred to the corrosion of steel tube, and G. Schuhmann dealt with casing used in oil wells, in which iron withstood the corrosive influences much better than steel. The corrosion of roofing was dealt with by E. S. Cook and C. L. Houston, while A. S. Cushman referred to the occurrence of corrosion in wire fencing.

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* *Iron Age*, vol. lxxvii. pp. 2055, 2060.
† *Ibid.*, pp. 2047-2049.

The paper communicated to the American Society for Testing Materials by H. M. Howe,* dealing with the causes for the difference in the susceptibility of iron and steel to corrosion in mechanical structures, has been published in full. The influences of blow-holes, of manganese, and of the presence of cementite in the steel, and of cinder in the wrought iron, are exhaustively discussed.

W. H. Fowler † deals with corrosion in steam-boilers and its effects.

O. Bauer ‡ deals with the influence of the presence of aluminium and tungsten on the corrosion of steel in dilute sulphuric acid.

A. A. Knudson § discusses electrolysis and its effect on the corrosion of underground pipe and water-mains. He gives the various remedies which have been essayed from time to time, including more perfect bonding, making pipes part of the return circuit insulation, and, specially, the insulation of joints.

Tests as to the relative corrosion of iron pipes and of "spellerised" steel pipes used for sulphurous water in coal-mines, are described.‖ The results were found to be greatly in favour of the "spellerised" steel.

Preservation of Iron and Steel Surfaces.—A. B. Harrison ¶ deals with protective coatings for steel. He divides them into three classes: linseed oil paints, varnish and enamels, and carbon coatings. No coating will protect a steel surface unless it is absolutely waterproof, while the bond between the coating and the metal should be perfect. The life of a paint depends upon the life of the oil, and by special treatment the latter can be prolonged so as to withstand the action of the strongest paint removers. He advocates a carbon covering, with a coating of the specially prepared oil-paint over it.

The durability of paints, with special reference to the protection of iron and steel surfaces from corrosion, is discussed.**

L. H. Barker †† gives an account of results obtained in protecting iron and steel structures with a cheap paraffin paper.

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* *Engineering Magazine*, vol. xxxi. pp. 750–752; *Iron Age*, vol. lxxvii. pp. 2056–2057.

† *Mechanical Engineer*, vol. xvii. pp. 319, 368, 391, 640.

‡ *Mitteilungen aus dem Königlichen Materialprüfungsamt*, vol. xxiii. pp. 292–298.

§ *Cassier's Magazine*, vol. xxx. pp. 337–342.

‖ *Iron Age*, vol. lxxviii. pp. 80–81.

¶ *Ibid.*, pp. 152–153.

** *Engineering*, vol. lxxxi. pp. 90–91.

†† *Railway and Engineering Review, Chicago*, August 19, 1905, p. 601; *Minutes of Proceedings of the Institution of Civil Engineers*, vol. clxiv. p. 455.

CHEMICAL ANALYSIS.

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I.—*ANALYSIS OF IRON AND STEEL.*

Determination of Carbon.—C. M. Johnson * gives a method for the determination of carbon in steel by direct ignition with red lead, a method which is also applicable to ferro-alloys. The drillings of the sample are shaken with about three times their weight of red lead, transferred to a porcelain boat, and subjected to combustion in a stream of oxygen. The carbon dioxide evolved is absorbed in barium hydrate solution, and the resulting carbonate is dried, ignited, and weighed. The samples should be drilled with flat-bitted drills to secure drillings of uniform small size. Combustion is completed in fifteen to twenty minutes.

H. E. Diller † presents the report of the Committee of the American Foundrymen's Association on Standard Methods of Analysis of Iron, dealing with the method recommended for the determination of carbon. The disposition of the apparatus is carefully regulated, and the sequence of the operations carefully described.

According to J. A. Aupperle ‡ the sample is burnt in a current of air or oxygen in an Aupperle crucible, and the resulting carbon dioxide is absorbed in standardised barium hydroxide solution. The free alkali is then at once titrated with standard hydrochloric acid without removing the precipitated barium carbonate.

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* *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xxi. pp. 586–602; *Journal of the American Chemical Society*, vol. xxviii. pp. 862–877.

† *Iron Age*, vol. lxxvii. pp. 1902–1903.

‡ *Journal of the American Chemical Society*, vol. xxviii. pp. 858–862.

S. H. Collins [*] describes a modification of Scheibler's apparatus, in which a small bulb is placed above the decomposition flask to prevent the acid from splashing up into the rubber tubes. This bulb, together with the rubber connecting tube, has a capacity of about 15 cubic centimetres. If 15 cubic centimetres of gas pass into the burette, no carbon dioxide passes into the burette at all; the error due to absorption is therefore nil. If 30 cubic centimetres of gas pass into the burette, there will be only 8·8 per cent. of carbon dioxide in the latter. Gas of such concentration would need 3·4 cubic centimetres of water to be saturated before 0·3 cubic centimetre had been absorbed; hence an error of 1 per cent. is impossible. The whole of the apparatus described is enclosed in a large vessel containing water.

L. Fricke [†] gives an illustration of the apparatus used for the determination of the total carbon in iron and steel at the Peine rolling-mills. It is claimed that it is cheaper to work in practice than are the ordinary apparatus. If a part is broken, it can be replaced without having to buy a whole new apparatus. The sample is dissolved in chromo-sulphuric acid.

E. Jaboulay [‡] describes apparatus he has devised for determining the carbon in iron alloys.

A. Kleine [§] illustrates an apparatus for the determination of carbon in iron and steel which in practice has given very good results. It is based on the use of chromo-sulphuric acid as a solvent.

Determination of Manganese.—N. Tarugi [||] gives details of a method for determining small quantities of manganese, based on the fact that manganous hydroxide is soluble in glycerol, and that the solution, on oxidisation by oxygen or sodium hypochlorite, forms a red colour, the intensity of which is proportional to the amount of manganese present. The presence of iron and nickel do not affect the reaction, but copper and cobalt interfere if the concentration of the manganese is less than 1 in 1000.

In the method proposed by F. Kietreiber [¶] 2 grammes of cast iron are dissolved in 20 cubic centimetres of hydrochloric acid, 150 cubic centimetres of water are added, and the solution is boiled with addition of 2 grammes of potassium chlorate. Three cubic centimetres of sulphuric acid are added, and the whole evaporated until sulphuric fumes appear. The residue is rinsed into a litre flask, a sufficiency of zinc oxide is added, and the whole diluted up to the mark. Two hundred and fifty cubic centimetres of the filtrate are then largely diluted, mixed with 20 cubic centimetres of 10 per cent. zinc sulphate solution, and, after adding two drops of dilute nitric acid, titrated at the boiling temperature with permanganate. Another 250 cubic centimetres may be acidified with sulphuric acid and titrated with permanganate in the cold. Schneider's process may be applied as a check. 0·5 gramme of the sample is ignited for an hour in a muffle with 0·5 gramme of sodium carbonate and 2 grammes of magnesium carbonate. The mass is dissolved in 25 cubic centimetres of dilute hydrochloric acid (1 : 2), mixed with 25 cubic centimetres of dilute sulphuric acid, neutralised with zinc oxide, and diluted to 1 litre. Five hundred cubic centimetres of the filtrate are then titrated with permanganate according to Volhard's method.

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[*] *Journal of the Society of Chemical Industry*, vol. xxv. pp. 518–522.

[†] *Stahl und Eisen*, vol. xxvi. p. 666, with one illustration.

[‡] *Revue Générale de Chimie pure et Appliqué*, 1906, p. 178.

[§] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. p. 531, with one illustration.

[||] *Gazzetta de la Societa Chimica*, vol. xxxvi. pp. 332–347.

[¶] *Oesterreichische Chemiker Zeitung*, vol. viii. pp. 565–566.

Determination of Sulphur.—H. E. Diller* describes the following method for the determination of sulphur recommended by the Committee on Standard Methods of Iron Analysis. Three grammes of drillings are slowly dissolved in concentrated nitric acid, in a platinum dish covered with an inverted watch-glass. After solution, 2 grammes of potassium nitrate are added, and the solution is evaporated to dryness and ignited at a red heat. Fifty cubic centimetres of a 1 per cent. solution of sodium carbonate are added, the contents boiled for a few minutes, filtered and washed with hot 1 per cent. sodium carbonate solution. The filtrate is acidified with hydrochloric acid, taken to dryness, and taken up with 50 cubic centimetres of water and 2 cubic centimetres of concentrated hydrochloric acid, filtered, washed, diluted to about 100 cubic centimetres, precipitated with barium chloride, filtered, washed well with hot water, ignited, and weighed.

According to J. McFarlane† and A. W. Gregory, when pig iron is dissolved in hydrochloric acid, a not inconsiderable portion of the sulphur may escape conversion into hydrogen sulphide. The authors, therefore, have modified the original method, and proceed as follows. Five grammes of the powered sample are intimately mixed with 0·5 gramme of potassium hydrogen tartrate; the mixture is wrapped in filter paper, placed in a covered crucible, and heated to bright redness for fifteen minutes. The mass will now give up all its sulphur as hydrogen sulphide when treated with dilute hydrochloric acid (2 : 1) in the usual apparatus.

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* *Iron Age*, vol. lxxvii. pp. 1902–1903.

† *Chemical News*, vol. xciii. p. 201.

An article by the late C. Reinhardt * on the determination of sulphur in iron deals especially with the volumetric methods of determination. The apparatus used is illustrated and described, as well as the various reagents needed, and the process itself is shown to be both accurate and rapid. It depends on the solution of the steel or pig iron in hydrochloric acid of 1·19 specific gravity, passing the gases evolved through an ammoniacal solution of cadmium acetate, treating the filtered cadmium sulphide with a known quantity of iodine solution in the presence of hydrochloric acid, and then titrating back the excess of iodide by a standard thiosulphate solution.

A. Kleine † describes and illustrates a modification of the apparatus he employs for the determination of arsenic with a view to its use for the determination of sulphur.

R. Baumann ‡ describes a simple method for detecting the distribution of sulphide particles in sections of iron or steel. A piece of photographic silver bromide paper is soaked in dilute sulphuric acid, allowed to drain, and then pressed against the surface of the section of iron, which has previously been ground flat and cleaned from grease. At parts where sulphide particles are present, hydrogen sulphide is evolved, and produces a blackening of the paper, which can afterwards be fixed and washed in the usual manner.

W. Schulte § deals with various methods for the determination of sulphur in iron, and describes a modified hydrogen sulphide method. The desirability of using strong instead of dilute hydrochloric acid for the solution of the metal is urged.

Determination of Phosphorus.—A. Grabe ‖ describes a rapid method for the determination of phosphorus in iron and iron ores.

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* *Stahl und Eisen*, vol. xxvi. pp. 799–806.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 530–531, with one illustration.

‡ *Metallurgie*, vol. iii. pp. 416–417.

§ *Stahl und Eisen*, vol. xxvi. pp. 985–991, with one illustration.

‖ *Bihang till Jernkontorets Annaler*, 1906, pp. 71–81.

F. Fettweis [*] discusses the influence of phosphorus on the solubility of carbon in iron.

Determination of Chromium.—H. E. Walters [†] describes a method for the determination of chromium in steel by the use of ammonium persulphate. 125 grammes of the sample are dissolved in 35 cubic centimetres of 1:5 sulphuric acid, and after warming and dissolving, a little ammonium persulphate is added to oxidise the iron and carbonaceous matter. The solution is diluted to 100 cubic centimetres and 40 cubic centimetres of silver nitrate solution (0·16 grammes $AgNO_3$) added, together with an excess of ammonium persulphate (5 to 7 grammes). It is then boiled for five minutes, cooled, and transferred to a 500 cubic centimetre flask, and made up to the mark. One hundred cubic centimetres are withdrawn, and the remainder mixed with a measured volume of ferrous sulphate solution and titrated with standard permanganese solution. The 100 cubic centimetres withdrawn are separately titrated with sodium arsenite, and the difference in the results serves as a basis for the calculation of the amount of chromium present.

To the new edition of A. A. Blair's "Chemical Analysis of Iron" [‡] there have been added chapters on chrome-tungsten steels and ferro-tungsten.

Determination of Vanadium.—J. Kent Smith [§] gives a summary of the static and dynamic properties of various types of vanadium steel. The following method is recommended for the rapid estimation of vanadium in steel. One gramme of the sample is dissolved in about 40 cubic centimetres of 25 per cent. nitric acid; when cool, the solution is agitated momentarily with 2 grammes of sodium bismuthate and filtered quickly; the filtrate and washings are decolorised with a few cubic centimetres of strong ferrous sulphate solution and 10 cubic centimetres of freshly-prepared hydrogen peroxide solution, and the whole is then made up to 100 cubic centimetres. The amount of vanadium present is then estimated by comparing the colour of the solution with comparison tubes.

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[*] *Metallurgie*, vol. iii. pp. 60–62.

[†] *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xxi. pp. 465–468.

[‡] Sixth edition. Philadelphia: J. B. Lippincott Company. 1906. Price 18s. net. A copy has been presented to the Institute library.

[§] *Journal of the Society of Chemical Industry*, vol. xxv. pp. 291–295.

Determination of Arsenic.—A. Kleine[*] describes a simplified form of distillation apparatus for the determination of arsenic in iron ores, iron, and steel.

Detection of Nickel.—C. Reichard[†] gives a new reaction for the detection of nickel. The solution is mixed with methylamine hydrochloride and heated in a porcelain capsule until white fumes are evolved. A deep blue colour results, which disappears on cooling and reappears on heating, as long as any methylamine remains. Cobalt, in similar circumstances, gives a dark blue colour, which does not immediately disappear on cooling.

Chemistry in the Machine-Shop.—H. S. Brown[‡] emphasises the need for analyses being supplied in the foundry and machine-shop, in order to secure that metal of the most appropriate chemical composition may be employed in making machinery. This requirement applies not only to steel parts, but to castings as well. Material used should be such as will subsequently machine well, without much cost, and such material can be better selected by chemical analysis than by relying upon the ordinary physical tests alone. The chemist is, in many cases, the best judge as to what constitutes a proper "mixture" for special purposes, and he instances cases where neglect in recognising that this is so has led to loss and disaster. Thus, in cutting screws, the chemical composition is a very useful guide as to the hardness and general suitability of the material, otherwise, if the steel be too hard, threads may be broken off in tapping; while bolts, if too soft, will stretch and become useless for securing tight joints, and screws, in similar circumstances, will undergo an alteration in pitch. He advocates having detail parts supplied to the shop tabulated, with an analysis entered opposite each piece. A copy should be kept in the purchasing department, so that new parts can be bought to the required chemical specification, and an analysis made of the newly purchased goods, to see that they correspond with the composition found most suitable.

W. M. Carr[§] gives details of methods for the rapid estimation of silicon, phosphorus, manganese, sulphur, and carbon in iron and steel, suitable for foundries, where results are desired speedily.

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[*] *Stahl und Eisen*, vol. xxvi. pp. 664–665, with one illustration.

[†] *Chemiker Zeitung*, vol. xxx. pp. 556–557.

[‡] *Iron Age*, vol. lxxvii. pp. 1746–1748.

[§] *Iron Trade Review*, July 12, 1906, pp. 26–29.

A description has appeared* of the new metallurgical laboratory at the works of Kynochs, Ltd., Birmingham. The laboratory is fully equipped both for routine work and for research.

II.—*ANALYSIS OF IRON ORES AND SLAG.*

Analysis of Iron Ores.—G. Chesneau † continues his contribution on the theoretical principles underlying the analysis of minerals. He discusses the electrolytic principles involved in double decompositions, with special reference to the investigations of Pfeffer, Vries, and of Van't Hoff, and criticises the views of Arrhenius and the ionisation of electrolytes. He discusses the methods to be adopted in order to render precipitation complete, with special reference to the influence of the addition of an excess of the reagent employed, in which connection he deals with the solubility of barium sulphate in solutions of barium chloride, hydrochloric acid and water. He next discusses the methods for securing the solution of samples insoluble in water or in acids. Volumetric methods are dealt with at length, and the nature of the indicators usually employed and their influence in rendering the end reaction more readily ascertainable is discussed. The employment of hydrolysis in cases where it is practicable is next dealt with, with special reference to the separation of oxides of metals by means of acetic acid.

V. Macri ‡ recommends that the solution freed from silica be divided into three portions. In the first, iron, aluminium, and manganese are precipitated by adding ammonium chloride, ammonia, and bromine; in the second portion, the iron is titrated with stannous chloride; and in the third, the manganese is titrated according to Volhard's method after removing iron and aluminium with zinc oxide.

Recent progress in iron ore analysis is summarised by O. Brunck.§

Determination of Iron.—Sources of error in the titrametric determination of iron with permanganate are discussed by H. Kinder || and by P. Lehnkering.¶ According to the former authority, the use of ferrous ammonium sulphate or electrolytically precipitated iron

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* *The Kynoch Journal*, vol. vii. pp. 121–126, with six illustrations.

† *Annales des Mines*, vol. ix. pp. 255–315, and 373–440.

‡ *Moniteur Scientifique*, vol. xx. p. 18.

§ *Chemiker Zeitung*, vol. xxx. pp. 777–780.

|| *Ibid.*, pp. 631–632.

¶ *Ibid.*, pp. 723–724.

for the standardisation of permanganate, is attended with slight sources of error on account of possible impurities in these substances. Good results are obtained by standardising with a pure iron of known composition, the amount being found by determining the various impurities, and then estimating the iron by difference; a trace of copper, however, counts as iron. In the titration process, when the iron is reduced to the ferrous state by means of stannous chloride, the excess of which is then removed with mercuric chloride, it is of great importance to wait for some twenty-five seconds before commencing the titration, as otherwise the reduction of the mercury may not be complete.

L. Brandt * describes the titration of iron with dichromate. The ferrous solution, which should contain 0·2 to 0·7 gramme of metal, and from 60 to 80 cubic centimetres of hydrochloric acid of specific gravity 1·12, is added to 1500 cubic centimetres of water containing 100 cubic centimetres of Reinhardt's manganese solution (6 kilogrammes manganous sulphate, 33 litres dilute sulphuric acid (1 : 3), 3 litres phosphoric acid of specific gravity 1·7, water up to 60 litres). Five cubic centimetres of an indicator, prepared by dissolving 0·1 gramme of diphenylcarbazide in 35 cubic centimetres of strong acetic acid and diluting to 100 cubic centimetres, are added, and standard potassium dichromate solution is run in until the liquid turns violet.

D. L. Randall † indicates certain conditions under which amalgamated zinc can be employed for the reduction of ferric chloride solutions in the volumetric estimation of iron.

V. Komar ‡ gives a process for the determination of iron in the presence of zinc. The mixed salts are converted into sulphates, and dissolved in the smallest possible volume of cold sulphuric acid. The solution is oxidised with nitric acid and evaporated to dryness, being subsequently ignited in a crucible until constant weight is obtained. The contents of the crucible are then extracted with water, which dissolves all the unchanged zinc salt and leaves the iron undissolved as ferric oxide.

Determination of Phosphoric Acid.—E. Guerry § and E. Toussaint describe the precautions to be observed in determining phosphoric acid by the citric method, and discuss the causes of error which frequently vitiate the result. The use of sulphuric acid, which expels hydrochloric acid and renders the silica insoluble, is advocated in the earlier stages of the analysis.

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* *Zeitschrift für analytische Chemie*, vol. xlv. pp. 95–99.

† *Zeitschrift für anorganische Chemie*, vol. xlviii. pp. 389–392.

‡ *Chemiker Zeitung*, vol. xxx. pp. 31–32.

§ *Bulletin de la Société Chimique de Belgique*, vol. xx. pp. 167–198.

Determination of Silica.—According to G. Dean [*] 1 gramme of the ore is boiled with 25 cubic centimetres of hydrochloric acid, and when all is dissolved a few drops of nitric acid are added, and the whole is evaporated to dryness. The residue is boiled with hydrochloric acid, slightly diluted with water, and the undissolved portion is collected on a filter and washed with hot acid (1 : 1). It is then transferred to a platinum crucible and ignited for a few minutes. When cold, the residue is transferred to a beaker and boiled for eight minutes with strong hydrochloric acid. The insoluble matter, which may now be regarded as practically pure silica, is collected and weighed as usual; the filtrate is added to the first, or main, filtrate.

III.—*ANALYSIS OF FUEL.*

Sampling of Coal.—A. Bement [†] deals with the importance of selecting a thoroughly representative sample for analysis. The word combustible used to designate a fuel free from ash and moisture is, in the author's opinion, erroneous, and the expression pure coal is proposed instead.

Coal Analysis.—The methods of fuel analysis for steam users are described in detail by J. B. C. Kershaw,[‡] with illustrations of the apparatus.

Coal-testing in the United States is described by J. S. Burrows.[§]

W. Bertelsmann [||] gives a summary of recent progress in the investigation of fuel.

Petroleum Analysis.—The determination of sulphur in petroleum and bituminous minerals is described by F. C. Garrett [¶] and E. L. Lomax.

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[*] *Journal of the American Chemical Society*, vol. xxviii. pp. 882–883.

[†] *Ibid.*, pp. 632–639.

[‡] *Engineer*, vol. cii. pp. 314–316, 337–338.

[§] *Times Engineering Supplement*, 1906, p. 315.

[||] *Chemische Zeitschrift*, vol. v. pp. 219–222.

[¶] *Journal of the Society of Chemical Industry*, vol. xxiv. pp. 1212–1213.

IV.—*ANALYSIS OF GAS.*

New Forms of Apparatus for Gas Analysis.—Several improved types of apparatus for gas analysis have recently been noticed. New Orsat apparatus for technical gas analysis are described by F. Bendemann.*

Louis de Saint Martin† connects the Orsat apparatus with a manometer, thus enabling the operator to read off the volume of the gas before and after treatment with absorbents at the ordinary pressure.

Illustrations ‡ are given of the Orsat apparatus as modified by C. Hahn. The modification consists in the use of specially constructed absorption vessels, a new arrangement of the burettes and change in the combustion arrangements.

Recent advances in gas analysis are summarised by H. Alexander.§

The optical analysis of industrial gases is described by F. Haber.||

Determination of Carbon Monoxide.—A. Gautier ¶ and P. Clausmann describe certain difficulties in the determination of carbon monoxide in gaseous mixtures, and the precautions to be observed to secure complete absorption. The residual gases left after absorption by the usual reagents, or after explosion with oxygen, should be passed over iodic anhydride heated to 70° C., which oxidises the last traces of carbon monoxide present.

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* *Zeitschrift des Vereines deutscher Ingenieure*, vol. l. p. 454.

† *Annales de Chimie analytique*, vol xi. pp. 96–98.

‡ *Stahl und Eisen*, vol. xxvi. pp. 665–666, with four illustrations.

§ *Chemiker Zeitung*, vol. xxx. pp. 657–659.

|| *Zeitschrift für angewandte Chemie*, vol. xix. pp. 1418–1422; *Zeitschrift für Elektrochemie*, vol. xii. pp. 519–520.

¶ *Comptes Rendus*, vol. cxlii. pp. 485–491.

STATISTICS.

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I.—*UNITED KINGDOM.*

Mineral Statistics.—According to the official statistics* the British production of iron ore in 1905 amounted to 14,590,703 tons.

The production of pig iron in 1905 is officially stated to have been 9,608,086 tons. In its production 23,050,782 tons of iron ore and 19,255,555 tons of coal were used. There were 345 furnaces in blast.

The total output of coal was 236,128,936 tons, which is the largest on record. The consumption of coal in the United Kingdom amounted to 168,968,291 tons, or nearly 4 tons per head of the population. 19,255,555 tons of coal were used in blast-furnaces for making pig iron. The quantity of coal exported, exclusive of coke, patent fuel, and coal shipped for use of steamers engaged in foreign trade, was 47,476,707 tons, an increase of nearly 1,250,000 tons compared with the preceding year. If the quantities of patent fuel, coke, and coal shipped for use of steamers engaged in foreign trade be added, the total amount of coal which left the country was 67,160,645 tons.

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* *Mines and Quarries: General Report and Statistics for* 1905. Part III. [Cd. 3196.] Price 1s. 6d.

The second part of the General Report on Mines and Quarries, dealing with labour, has been issued.* It shows that the total number of persons employed at British mines and quarries in 1905 was 982,343, of whom 887,524 were employed at mines and 94,819 at quarries. During the year, 1103 separate fatal accidents occurred at mines and quarries, causing the loss of 1304 lives. Compared with the previous year, there is a decrease of 55 in the number of fatal accidents, and an increase of 102 in the number of lives lost. The general death-rate from accidents at mines was 1·358 per 1000 persons employed. Of the fatal accidents at mines, 44·8 per cent. were caused by falls of ground. Five fatal accidents were caused by the use of electricity underground. A very unusual accident is reported at Llanhilleth Colliery, where one man was killed and six men injured by the sudden blast of air caused by a fall from the side of a cavity. Some interesting statistics are given showing that gunpowder constituted more than 67 per cent. of the total weight of explosives used in collieries. About 30 per cent. of the weight used consisted of permitted explosives, those most largely used being bobbinite, saxonite, ammonite, roburite, and westfalite. Other statistics show that there were 295 collieries where coal-cutting machines were at work, the total number of machines being 946. The total quantity of coal obtained by the aid of these machines in 1905 was 8,102,197 tons.

The coal resources of the United Kingdom are reviewed by J. L. Pultz.†

G. T. Beilby,‡ in his presidential address before the University Engineering Society, Glasgow, discusses some of the wider aspects of modern power production for industrial purposes, more particularly with reference to the fuel resources of the country.

Iron Trade Statistics.—The British Iron Trade Association § shows that the total make of pig iron in Great Britain for the first half of 1906 was 4,905,424 tons, which is at the rate of 9,810,848 tons a year. The same authority also gives the production of other products in the first half of 1906, as follows: Bessemer steel ingots, 919,620 tons, against 1,019,887 tons in the first half of 1905 and

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* Cd. 3179, price 10d.

† *Engineering and Mining Journal*, vol. lxxxii. pp. 17–18.

‡ *Nature*, vol. lxxiii. p. 398.

§ *Iron and Coal Trades Review*, vol. lxxiii. pp. 909, 999, 1089.

865,683 tons in the first half of 1904. Bessemer steel rails, 487,184 tons, against 540,314 tons in the first half of 1905. Open-hearth steel ingots, 2,196,853 tons, against 1,980,095 tons in the first half of 1905, and 1,670,129 tons in the first half of 1904. Acid and basic steel ingots amounted to 2,196,853 tons, 1,638,667 tons of which were acid. Open-hearth plates, angles, and bars, 1,760,279 tons, and open-hearth steel rails, 52,458 tons. Figures are also given showing that the output of pig iron per furnace in operation was 13,501 tons, and that the average number of furnaces in blast during the first half of the year was 363 out of a total of 515 built.

A return issued by the Board of Trade * shows that the production of pig iron in the United Kingdom rose from 7,904,000 tons in 1890 to 9,593,000 tons in 1905. The increase in the case of the United States was from 9,203,000 tons to 22,992,000 tons, and in that of Germany from 4,576,000 tons to 10,700,000 tons. As regards steel, the production of the United Kingdom increased in the period named from 3,579,000 tons to 5,812,000 tons; that of the United States from 4,277,000 tons to 19,913,000 tons; and that of Germany from 2,196,000 tons to 10,067,000 tons.

Coke.—Official statistics relating to the manufacture of coke and briquettes in the United Kingdom have been published † for the first time. The production of coke in 1905 was 18,037,985 tons, and that of briquettes was 1,219,586 tons. There were 31,060 coke ovens in use. Of these 25,514 were beehive ovens, 2233 Coppée ovens, 726 Simon-Carvés ovens, 503 Otto-Hilgenstock ovens, 470 Semet-Solvay ovens, 72 Koppers ovens, 52 Bauer ovens, and 1490 other kinds.

Metallurgical Education.—An illustrated description has appeared ‡ of the new extensions of the Armstrong College, Newcastle-on-Tyne.

The growth of the metallurgical department of Sheffield University is traced § from its beginning as a department of Firth College in 1885, with the late W. H. Greenwood as lecturer on metallurgy. In 1889 J. O. Arnold was appointed to the chair of metallurgy, which he holds at the present time. The article is illustrated by a portrait of J. O. Arnold in the micro-laboratory.

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* *Iron and Steel*, 1905; *Statistical Tables*, 322, price 3d.

† *Mines and Quarries: General Report and Statistics.* Part III. [Cd. 3196.]

‡ *Iron and Coal Trades Review*, vol. lxxiii. pp. 1–2.

§ *Nature*, vol. lxxiv. pp. 541–543.

G. H. Winstanley* deals with mining education as given at the Victoria University at Manchester.

II.—*AUSTRALASIA.*

Mineral Statistics of Victoria.—According to the official statistics,† the production of coal in Victoria in 1905 amounted to 155,135 tons, valued at £79,035. The output shows an increase of 33,394 tons, as compared with the quantity produced during 1904.

Mineral Statistics of Western Australia.—According to official returns,‡ the output of coal in Western Australia during 1905 amounted to 127,364 tons. The value of the ironstone raised during the year was £1285, and that of limestone £1220.

Mineral Statistics of Queensland.—The production § of coal in Queensland in 1905 was 529,326 tons.

Mineral Statistics of Tasmania.—According to official returns,|| the output of coal in Tasmania in 1905 amounted to 51,993 tons, of the value of £44,194.

Mineral Statistics of New Zealand.—According to the official statistics,¶ the coal and lignite production of New Zealand in 1905 showed an increase of 47,918 tons in comparison with the previous year, the total output being 1,585,756 tons.

Mineral Statistics of South Australia.—According to the report of the Government Resident,** the exports from the Northern Territory of South Australia in 1905 included 63 tons of tungsten ore valued at £3379. Active prospecting for coal was in progress during the year.

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* *Transactions of the Institution of Mining Engineers*, vol. xxx. pp. 437–442.

† *Annual Report of the Secretary for Mines*, p. 25, Melbourne, 1906.

‡ *Annual Report of the Department of Mines*, p. 6. Perth, 1906.

§ *Bulletin of the American Iron and Steel Association*, vol. xl. p. 123.

|| "Tasmania." Report of the Secretary for Mines for Half-Year ending December 31, 1905. (Hobart: Department of Mines.)

¶ *New Zealand Mines Record*, vol. x. p. 23.

** *Board of Trade Journal*, vol. lv. p. 614.

III.—*AUSTRIA-HUNGARY.*

Mineral Statistics of Austria.—The official Austrian statistics * for the year 1905 show that the production was as follows:—

	Metric Tons.
Iron ore	1,913,782
Manganese ore	13,788
Coal	12,585,263
Brown-coal	22,692,076
Graphite	34,416
Brown-coal briquettes	82,729
Coal briquettes	136,059
Coke	1,400,283
Forge pig iron	947,035
Foundry pig iron	172,579
Total pig iron	1,119,614

The quantity of iron ore mined per miner employed amounted to 399 tons. No nickel or cobalt ores were mined during the year. The coal-mines gave employment to 66,072 workpeople; the brown-coal mines to 53,189; the iron ore mines to 4796, and the ironworks to 6160. There were altogether 62 blast-furnaces, 37 of which were in blast for 1574 weeks.

The Austrian Government has published a report on the average efficiency of miners in the Austrian coal-mines in 1901, 1903, and 1904. The Nine-Hours Day Act came into force on July 1, 1902. At 175 mines the work done per shift was more, and at 78 mines it was less, than in 1901.

Statistics of iron-ore mining in Moravia and Austrian Silesia are given by J. Lowag.†

In the mining district of Brünn ‡ there were in 1905 three active colliery undertakings. Two seams are mined, one being 6 to 16 feet in thickness, and the other from 2 to 6 feet or so. There are six winding shafts in operation, and the quantity of coal raised in 1905 amounted to 440,000 tons.

Petroleum in Galicia.—I. Gruskiewicz § gives an account of the present condition of the petroleum industry in Galicia.

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* *Statistiches Jahrbuch des k. k. Ackerbau-Ministeriums für das Jahr* 1905, Part i. p. 59; *Oestereichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 504–507 and 517–520.

† *Montan Zeitung*, vol. xiii. pp. 54, 70, 88, 104, 120, 136, 152.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 247–248.

§ *Moniteur du Pétrole Roumain*, vol. vii. pp. 543-544.

Iron Trade of Hungary.—A copiously illustrated monograph on the Vajdahunyadi iron mines and works, by G. Latinak,* contains much statistical information.

Mineral Statistics of Bosnia.—The official mineral statistics for Bosnia and the Herzegovina in 1905 † show that the production included :—

	Metric Tons.
Iron ore	122,540
Chrome ore	186
Manganese ore	4,129
Brown-coal	540,237
Pig iron	43,074
Castings	3,951
Open-hearth steel ingots	29,644
Wrought iron	23,200

The brown-coal mines gave employment to 1633 workpeople, the iron ore mines to 389, and the ironworks to 1081.

IV.—*BELGIUM.*

Mineral Statistics.—The Belgian production of coal in 1905 was 21,844,200 tons.‡ This represents the net production after washing and screening, and does not afford a fair basis of comparison with the figures given for the coal production in 1904, which showed a gross yield of 23,380,025 tons. The production of pig iron was 1,310,290 tons; 380,360 tons of wrought iron was produced, and 1,173,020 tons of steel.

Statistics of the Belgian mineral production in 1905, and a list of the Belgian mines in operation, are given. §

History of the Cockerill Works.—E. Mahaim ‖ gives an exhaustive account of the origin and development of the John Cockerill Works at Seraing. Established in 1807 for the manufacture of carding and spinning machines, the works employed, in 1813, 150 workmen, besides finding employment for a number of workpeople who did piecework at their own homes in the surrounding district. In 1905 the works consisted of twelve distinct departments, employed 9560 workmen, and possessed engines aggregating 13,000 horse-power. The founder, William Cockerill, was of English or Irish extraction, but became a naturalised French subject in 1810, and retired in 1813 in favour of his two sons, James and John, who purchased the castle of Seraing, which had formerly been a seat of the prince bishops of Liége, but had subsequently been used, first as a military hospital, and later as a powder magazine. Here the firm made great extensions, and commenced to build steam-engines and textile machinery on a large scale. In 1820 they decided to manufacture their own material, and obtained authority to construct a coke blast-furnace. This was the first application of this nature made in Liége, but the furnace, which was commenced in 1823 under the superintendence of Mushet, was not put in blast before 1826, being forestalled by the furnace built by Orban, at Grivegnée. Three years previously (1823), James Cockerill retired, and John became sole proprietor. In 1835 the first locomotive and the first rails were delivered to the State authorities for one of the earliest railways on the Continent, that from Brussels to Malines. John Cockerill died in 1840, and an interesting inventory is given of the works at the time of his death. In addition to Seraing, he owned six factories and workshops at Liége, six works in other parts of Belgium, nine in other parts of Europe, including Germany, Poland, Holland, and Spain, and was commencing the establishment of collieries at St. Etienne and of machine shops in St. Petersburg. John Cockerill left no direct heirs, and the business therefore became a limited company, of which his indirect heirs and the creditors of the firm became promoters. The enterprises conducted by the brothers in the earlier years of their association are described in detail.

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* *Banyaszati es Kohaszati Lapok*, vol. xxxix. pp. 73–74.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 312–314; *Stahl und Eisen*, vol. xxvi. p. 831.

‡ *Comité des Forges de France*, Bulletin No. 2574.

§ *Annales des Mines de Belgique*, vol. xi. pp. 375-414.

‖ *Revue Universelle des Mines*, vol. xiii. pp. 171-192.

The Liége Exhibition.—W. O'Connor * gives some notes on a visit to the Liége Exhibition.

V.—*CANADA.*

Mineral Statistics.—The value of the mineral production of the Dominion of Canada in 1905 amounted to £13,714,941, which is an increase of £1,700,000 over the previous year. The total production of pig iron in Canada during the first six months of 1906 was

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* *Proceedings of the South Wales Institute of Engineers*, vol. xxiv. pp. 409–426.

282,010 tons, as compared with 257,494 tons produced in the first half of 1905.*

Metallurgical Education.—The education of mining and metallurgical engineers as carried out at the McGill University, Montreal, is described by J. B. Porter.†

A. Stansfield ‡ gives a description of the equipment of the metallurgical laboratories at the McGill University.

VI.—*CEYLON.*

Mineral Resources.—R. Stokes § describes the mineral resources of Ceylon. W. R. Dunstan ‖ has published a report on the results of the mineral survey of Ceylon. Attention is paid to the occurrence of iron ore and of chromite.

VII.—*CHINA.*

Mineral Resources.—It is reported ¶ that the Chinese mining industry is making progress, and that in 1905 the exports of pig iron amounted to 12,211 tons.

VIII.—*FRANCE.*

Iron Trade Statistics.—Returns have been made ** of the pig iron produced in France during the first six months of 1906. The total amount was 1,573,504 tons, as compared with 1,499,802 tons during the corresponding period in 1905, an increase of 73,702 tons. The total includes 841,398 tons of basic pig iron, and 80,354 tons of acid Bessemer pig iron. The production of steel ingots amounted during the same period to 1,159,546 tons, as against 1,073,155 tons in the first six months of 1905.

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* *Engineer*, vol. cii. p. 371.

† *Canadian Mining Review*, vol. xxvi. pp. 112-120.

‡ *Ibid.*, pp. 121-127.

§ *Mining World*, vol. xxiv. pp. 464-465.

‖ *Colonial Reports*, No. 37. London, 1906. Price 2½d.

¶ *Montan Zeitung*, vol. xiii. p. 296.

** *Comité des Forges de France*, Bulletin No. 2618.

Iron Ore.—The iron ore deposits of France are estimated to contain 31,150,000 metric tons of ore, of which 30,000,000 tons is in Lorraine.*

Coal.—The following statistics have been published † of the coal production of France during the first half of 1906, as compared with the production during the corresponding period of 1905:—

	First Half of 1905. Metric Tons.	First Half of 1906. Metric Tons.
Coal and anthracite . . .	17,355,480	15,389,592
Lignite	339,939	367,757
Total	17,695,419	15,757,349

IX.—*GERMANY.*

Mineral Statistics.—The preliminary official returns ‡ show the production of the mines and smelting-works of Germany, including Luxemburg, in 1905 to have included:—

	Metric Tons.
Coal	121,298,167
Brown-coal	52,498,507
Iron ore	23,444,073
Manganese ore	51,463
Foundry pig iron	1,797,680
Direct castings	61,320
Bessemer pig iron	410,963
Basic pig iron	7,032,322
"Steel" iron and spiegeleisen	580,344
Forge pig iron	976,986
Scrap iron	15,446
Castings	2,045,477
Wrought iron and steel unmanufactured for sale . .	43,311
Wrought iron manufactures	787,277
Steel unmanufactured for sale	2,725,498
Steel manufactures	6,753,604

These figures show considerable increases in most cases compared with the similar outputs in the preceding year.

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* *Chemiker Zeitung*, vol. xxx. p. 737.
† *Board of Trade Journal*, vol. liv. p. 562.
‡ *Stahl und Eisen*, vol. xxvi. p. 748.

Iron Trade Statistics.—During the first half of 1906 * the production of pig iron in Germany was as follows:—

	Metric Tons.
Foundry iron	1,050,878
Bessemer iron	238,492
Basic iron	3,910,349
"Steel" iron and spiegeleisen	454,407
Forge iron	419,810
Total	6,073,936

During the similar period of the preceding year this production was only 5,098,588 tons.

The import of iron ores into Germany in 1905 † amounted to 6,085,196 tons. Of this quantity 1,642,457 tons was from Sweden.

An illustrated account of the iron industry of Rhineland and Westphalia has been published.‡

A report has been issued § showing that the Krupp establishment had, on April 1, 1906, no less than 62,553 employés, against 55,816 last year. Of this total 5065 are stated to be officials. The firm owns, besides the original works at Essen, the firing ground at Meppen, several works at Magdeburg and elsewhere, the Germania Shipyard at Kiel, coal and iron-mines in Germany and Spain, a shipping department, &c. The cast steel industry at Essen employs now 35,377 persons, against 29,903 last year. The workmen's dwellings number 4491, and there are, of course, hospitals, schools, recreation grounds, and buildings, &c. The firm paid for the year 1904 a sum of 2,489,471 marks, in accordance with the insurance laws of the German Empire, of which 1,162,058 marks were for insurance against accidents, 953,738 marks for insurance against sickness, and the rest for insurance against disablement. A still larger sum was paid in contributions of various kinds, compulsory and otherwise, the aggregate sum amounting to 5,694,606 marks.

F. Diepenhorst ‖ observes that in June 1906 the Burbach Ironworks Company had been in existence for fifty years. The history of the works during this period is sketched, and illustrations are given of it in the year 1859, 1889, and at the present time, showing very forcibly the enormous increase in its size that has taken place during the last half-century. At present it gives employment to 4500 workpeople, has a capital of £2,750,000, a turnover in 1904 of £1,390,000, and a net profit of £151,600. The original capital was £44,000.

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* *Stahl und Eissen*, vol. xxvi. p. 951.

† *Ibid.*, p. 676.

‡ *Energy*, vol. i. No. 4.

§ *Engineering*, vol. lxxxii. p. 200.

‖ *Stahl und Eisen*, vol. xxvi. pp. 1229–1234, with three illustrations.

Coal.—Articles by C. Jüngst[*] on labour in the Rhenish-Westphalian collieries have been reprinted in pamphlet form.[†]

The report of the Rhenish-Westphalian Coal Syndicate shows that the output of the syndicated collieries in 1905 was 65,382,522 tons, or 2·79 per cent. less than in 1904.

B. Simmersbach[‡] has published a monograph of 96 pages on the economic development of the Gelsenkirchen Colliery Company. In the thirty-two years of its existence the company has paid to its shareholders dividends amounting to £4,523,374, an average of 8·99 per cent. on the capital invested. This represents a clear profit of 1s. 1½d. per ton on the 79,601,814 tons of coal raised since 1873. The development of the Gelsenkirchen Colliery thus forms a brilliant feature in the history of the Rhenish-Westphalian mining industry.

Mineral Statistics of Prussia.—In 1905[§] the Prussian mineral production included, in metric tons, coal 113,000,657, brown-coal 44,148,751, asphalt 28,872, petroleum 57,741, iron ore 4,130,210, nickel ore 10,432, and manganese ore 51,048.

Mineral Statistics of Bavaria.—In the year 1905[||] the mineral production of Bavaria included:—

	Active Mines or Works.	Work-people Employed.	Production.
			Metric Tons.
Coal	14	7990	1,178,360
Brown-coal	7	541	137,138
Iron ore	26	874	182,389
Graphite	65	293	4,921
Petroleum	1	30	...
Pig iron	3	475	94,242
Direct castings	1	...	24
Other cast-iron castings	104	7125	112,874
Bar iron	11	2336	36,459
Iron wire	...	...	17,375
Ingot metal	5	1213	134,755

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[*] *Glückauf*, vol. xlii. pp. 1282-1289, 1314-1326.

[†] Essen, 1906.

[‡] *Die Wirtschaftliche Entwicklung der Gelsenkirchener Bergwerks-Aktiengesellschaft von* 1873 *bis* 1904, by Bruno Simmersbach, 1906, price 2s. 6d. (Freiberg: Craz & Gerlach.)

[§] *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate Statistische Lieferung*, vol. liv. pp. 2-28.

[||] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. pp. 487-488.

Mineral Statistics of Saxony.—The official mineral statistics of Saxony for 1905 have been published.* The production of coal was 4,603,903 tons, that of brown-coal 2,167,731 tons, that of iron ore 270 tons, and that of tungsten ore 34 tons.

The Nuremberg Exhibition.—On May 15 the city of Nuremberg opened a national exhibition in commemoration of the centenary of its subjection to the Bavarian Crown. The exhibition, which remained open until October, proved eminently successful. It contained a good display of Bavarian manufactures, and was of special interest from the admirable manner in which the mineral resources of the kingdom were shown. The mineral deposits represented included the iron ores of the Fichtelgebirge, coal from the Palatinate, and graphite from Passau. O. Friz † describes the geological and mineral exhibits at the Bavarian National Exhibition, giving details of the occurrence and production of iron ore, brown-coal, graphite, and peat in Bavaria. The machinery exhibits are described by H. Dubbel. ‡

Iron Trade Statistics of Luxemburg.—The production § of iron ore in Luxemburg in 1905 amounted to 6,595,860 tons, as compared with 6,347,781 tons in the previous year. The number of iron ore mines was 75, and the total number of workpeople engaged at these, 6278. The consumption of the ore in Luxemburg amounted to 4,349,201 tons, or 66 per cent. of the output. In 1905, the year in question, the 32 blast-furnaces were in operation for 1552 weeks, and made 100,766 tons of forge pig iron, 1,098,154 tons of basic pig iron, and 169,331 tons of foundry iron. There were nine foundries, of which eight were in operation. These made 13,628 tons of castings. The steelworks numbered three. These produced 40,490 tons of ingots, 142,841 tons of semi-manufactures, and 214,611 tons of finished products. They employed 2902 operatives.

X.—*INDIA.*

Mineral Statistics.—According to official statistics || the output of coal in India in 1905 amounted to 8,417,739 tons, of which Bengal

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* *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen.* Freiberg, 1906, p. 68.

† *Zeitschrift für praktische Geologie*, vol. xiv. pp. 256–261.

‡ *Zeitschrift des Vereines deutscher Ingenieure*, vol. l. pp. 1567–1574.

§ *Stahl und Eisen*, vol. xxvi. pp. 1155–1156.

|| *Board of Trade Journal*, vol. lv. pp. 65, 124.

represents more than six-sevenths of the total output. The production of manganese ore in 1905 amounted to 204,194 tons, and 93,170 tons of limestone was produced.

B. Simmersbach * reviews the mining development of India.

C. M. Weld † has investigated the ore resources of the Tata Iron and Steel Company. An examination of the deposits at Chanda, Central Provinces, having proved unsatisfactory, those in the Raipur district were visited, and subsequently the deposits at Gurumaishini Hill, Orissa, were found to be so plentiful, and of such high quality that, in view of their accessibility, it was decided to start smelting in India. Fuel of satisfactory quality having been found in the Jherria coalfield, a convenient locality for assembling raw materials and marketing the production was fixed upon at Sini Junction, on the Bengal-Nagpur, where there is an adequate water supply. The ores employed will be drawn from those of Majurbhanj State, it being estimated that the available tonnage of ore in sight at Gurumaishini amounts to 7,500,000 tons. The ore contains on an average 61·85 per cent. of iron, 0·036 per cent. of sulphur, and 0·135 per cent. of phosphorus, but much of it contains only 0·064 per cent. of the latter element. At Dhullee-Rajara there is a reserve supply contained in lenses and pockets, trial borings made on the area, in conjunction with the visible outcrops, showing that, in a small proportion of the concession alone, 2,500,000 tons are available. This ore averages 67·45 per cent. of iron, 0·061 per cent. of phosphorus, 0·09 per cent. of sulphur, 1·08 per cent. of silica, and 0·16 per cent. of manganese. The Tata Iron and Steel Company will acquire a portion of the Jherria coalfield, at present held by the Indian Collieries Syndicate, Limited, estimated to supply 63,500,000 tons of workable coal, at depths varying from 300 to 1000 feet, with underlying deposits estimated at a further 11,600,000 tons. The coal is of good average quality, and yields a hard coke, the high ash of which can be greatly reduced by careful selection and washing of the coal previous to coking. Two blast-furnaces, 17 feet by 75 feet, will be erected, with a minimum annual capacity of 120,000 tons, and four 40-ton basic open-hearth furnaces will be laid down, together with a blooming-mill, and rail and beam mills. The output of steel,

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* *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. liv. pp. 308–314.

† A copy of this report has been presented to the Library. *Iron Age*, vol. lxxviii. pp. 69–73.

when the plant is in full working order, is anticipated to reach 85,000 tons per annum.

XI.—*ITALY.*

Mineral Statistics.—The production of iron ore in Italy in 1905 amounted to 366,616 tons, and that of manganese ore to 5384 tons. The production also included 428 tons of asphalt, 412,916 tons of mineral fuel, 10,572 tons of graphite, 17,823 tons of peat, and 3,092,000 cubic metres of natural gas. The production of pig iron was 143,079 tons, that of castings 38,169 tons, that of wrought iron 205,915 tons, and that of steel 244,793 tons.*

The Milan Exhibition.—Illustrated descriptions of the Milan Exhibition, celebrating the successful completion of the Simplon Tunnel, have been published by E. Lemaire,† W. Gentsch,‡ J. W. Chubb,§ and by others.‖

XII.—*JAPAN.*

Mineral Statistics.—The production of coal, iron, and petroleum in Japan continues to increase.¶ In 1905 the production of coal amounted to 11,630,000 tons.

XIII.—*NATAL.*

Coal.—The report for the year 1905 of the Natal Commissioner of Mines** deals with the discovery of a new coal-seam near Umlalazi, on the Zululand railway, 103 miles from Durban; the demonstration of the high quality of some of the coal in the Utrecht and Vryheid districts, by tests made by the Coal Testing Committee, and by other tests; and the attempts made to obtain a wider market for anthracitic coals, by mixing them with more bituminous coals, for use in ordinary boiler furnaces, and by using them alone in gas producers supplying gas direct to gas-engines. According to the official returns,* the coal production of Natal in 1905 was 1,129,407 tons.

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* *Rassegna Mineraria*, vol. xxv. pp. 224–225.

† *Génie Civil*, vol. xlix. pp. 81–87.

‡ *Zeitschrift des Vereines deutscher Ingenieure*, vol. l. pp. 625–628.

§ *American Machinist*, vol. xxix. pp. 209–211, 268–270.

‖ *The Builder*, October 6, 1906; *Nature*, vol. lxxiv. p. 46; *Engineering*, vol. lxxxi. pp. 248, 441, 492, 559, 625, 861; *Engineer*, vol. ci. p. 578.

¶ *Montan Zeitung*, vol. xiii. p. 362.

** *Board of Trade Journal*, vol. liv. p. 519.

XIV.—*PERU.*

Mineral Statistics.—The message of the President of the Republic of Peru to the Congress of 1906 states that in 1905 the production of coal was 72,665 tons, and that of petroleum 49,700 tons.†

In a paper on the mineral resources of Peru, L. M. Gottschalk‡ gives particulars of the occurrence of coal, petroleum, and molybdenite.

XV.—*PORTUGAL.*

Mineral Statistics.—Official statistics, cited by E. Ackermann§ in a memoir on the present condition of the mining industry in Portugal, shows that in 1904 the production included 12,805 tons of anthracite, 12,488 tons of iron ore, and 358 tons of tungsten ore. The iron ores‖ which were formerly exported to North America, at present go chiefly to England and Belgium. The ores are not smelted in the country, owing to the want of coal and railway communications. Iron-mines are found in the neighbourhood of the river Mira in Olemtejo; they are situated in the coalfield which extends from the Province Huelva in Spain to Cape Sinés in Portugal. The following shows the composition of typical Portuguese iron ores:—

	Per Cent.	Per Cent.
Iron	56·00	58·00
Manganese	7·42	2·84
Phosphorus	0·16	0·10
Sulphur	0·10	0·20
Silica	4·00	5·00

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* *Engineer*, vol. cii. p. 475.

† *Mining Journal*, vol. lxxx. p. 457.

‡ *Mining World*, vol. xxv. pp. 96–97.

§ *Chemiker Zeitung*, vol. xxx. pp. 543–544.

‖ *Revue Mineralurgique*, vol. iv. pp. 98–99.

XVI.—*RHODESIA.*

Coal.—The output of coal in Southern Rhodesia during the year ended March 31, 1905, amounted to 64,844 tons.[*]

XVII.—*ROUMANIA.*

Petroleum.—C. Alimaneshtiano[†] gives a history of the past forty years of the oil industry of Roumania, and E. B. Lazarovici[‡] discusses the concession of oil-bearing lands in that country.

A report has been published by L. Elefteresco,[§] prefect of the district of Prahova, on the accident at Boushténari on July 17, 1906, in which several oil wells and reservoirs were burned, and several lives lost.

XVIII.—*RUSSIA.*

Iron Trade Statistics.—The production in Russia in 1905[‖] in the districts mentioned was as follows:—

Pig Iron.

District.	Metric Tons.
South	1,690,740
Ural	673,660
Moscow	86,061
Volga	...
North and Baltic	12,861
Poland	251,741
Total	2,715,063

Iron and Steel Semi-manufactures.

District.	Metric Tons.
South	1,334,714
Ural	639,475
Moscow	132,051
Volga	165,081
North and Baltic	135,291
Poland	331,043
Total	2,737,655

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[*] *Board of Trade Journal*, vol. li. p. 411.

[†] *Moniteur du Pétrole Roumain*, vol. vii. pp. 345–348.

[‡] *Ibid.*, pp. 376–380.

[§] *Ibid.*, pp. 652–653.

[‖] *Vjestnik Finanzov; Stahl und Eisen*, vol. xxvi. p. 832.

Finished Iron and Steel.

District.	Metric Tons.
South	1,119,372
Ural	535,573
Moscow	123,116
Volga	138,693
North and Baltic	152,973
Poland	276,942
Total	2,346,669

B. Simmersbach * gives the history of a century of development in the Russian iron trade.

O. Rüschkoff † gives the Russian mineral statistics for 1903.

The mining industry of Russia's possessions in Central Asia is described by F. Thiess.‡

Manganese Ore.—The export of manganese ore from Brazil during the year 1904 amounted to 208,260 tons, as compared with 161,926 tons exported in 1903.§

The difficulties in the way of increasing the quantity of manganese ore mined in the Caucasus have hitherto consisted in the large number of small owners in whose hands the ore deposits lie, and in the very inadequate railway facilities on the one hand, and the excessive transport charges on the other. This has led to the rise of competitive ore fields. Thus the manganese ore imported from Russia into Germany was 161,416 tons in 1903, and 151,222 tons in 1905, whilst during the same period the Indian and Brazilian ores so imported have increased from 28,555 tons to 65,174 tons. ||

Metallurgical Industry of Russian Poland.—According to a despatch from A. P. Murray,¶ the greatest hindrance to the Polish metallurgical industry hitherto has been the necessity of importing coke, for which the coal in the Dombrova Basin is unsuitable. It is now stated that the coal discovered near Blizyn is suitable for making coke. If this is true, and if the beds are as extensive as would seem,

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* *Zeitschrift für das Berg-, Hütten und Salinenwesen im preussischen Staate*, vol. liv. pp. 382–413.

† *Glückauf*, vol. xlii. pp. 1351–1357.

‡ *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. liv. pp. 189–197.

§ *Board of Trade Journal*, vol. lii. p. 81; *Eisen-Zeitung*, vol. xxvii. p. 564.

|| *Torgov. Promyschl. Gaz.*; *Stahl und Eisen*, vol. xxvi. p. 631.

¶ *Board of Trade Journal*, vol. liv. p. 562.

the metallurgical industry in Poland will be placed on quite a different footing.

Mineral Statistics of Finland.—According to C. P. Solitander,* the production in Finland in 1904 of lake iron ore was 37,887 tons, the total production of iron ore being 47,213 tons. There were twelve blast-furnaces at eleven works, the total production being 16,165 tons of pig iron. The production of bar iron and steel was 21,492 tons.

XIX.—*SPAIN.*

Mineral Statistics.—Provisional statistics † for Spain for 1905 show an iron ore production of 9,395,314 tons, as compared with 7,964,748 tons in 1904. As usual, the Province of Viscaya produced considerably over one-half of the total output. The exports of iron ore in 1905 amounted to 8,590,483 tons, against 7,291,941 tons in 1904. The production of coal and lignite in 1905 amounted to 3,202,911 tons, against 2,975,909 tons in 1904.

Iron Trade Statistics.—The production of pig iron in 1905 ‡ amounted to 383,100 tons, against 386,000 tons in 1904. The total production of Bessemer steel ingots and castings amounted in 1905 to 113,664 tons, against 93,100 tons in 1904, and the production of open-hearth steel ingots and castings to 124,200 tons, as compared with 100,659 tons in 1904. The largest steel plant in Spain is operated by the Altos Hornos Company, which in 1905 made 168,500 tons of Bessemer and open-hearth steel ingots and castings.

Coal Resources.—At the suggestion of the Liga Maritima Española the Spanish Government, by a decree dated October 11, 1905, has appointed a Commission to inquire fully into the coal resources of Spain, and into those matters generally on which the successful commercial exploitation of these resources would depend. §

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* *Affärsvärlden*, vol. vi. p. 550.

† *Bulletin of the American Iron and Steel Association*, vol. xl. p. 59.

‡ *Ibid.*

§ *Austro-Hungarian Consular Report; Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. liv. p. 210.

XX.—*SWEDEN.*

Iron Trade Statistics.—The official statistics* show that in Sweden in 1905 there were 326 iron ore mines in operation, the output comprising 4,090,916 tons of magnetite, 273,917 tons of red hæmatite, and 1134 tons of lake iron ore. The number of blast-furnaces in operation was 129, of Lancashire hearths 275, of Franche-Comté hearths 10, of Walloon hearths 21, of scrap smelting hearths 13, of puddling-furnaces 3, of Bessemer converters 22, of open-hearth furnaces 57, of crucible steel furnaces 10, and of electric furnaces 3. The production of coal was 322,384 tons, that of fireclay 119,947 tons, and that of manganese ore 1992 tons. The metallurgical production included 539,437 tons of pig iron, 182,640 tons of blooms, 78,204 tons of Bessemer ingots, 288,675 tons of open-hearth steel ingots, 1319 tons of crucible steel ingots, 199,543 tons of iron and steel bars, 84,837 tons of iron and steel in bands and rods, 36,009 tons of wire rods, 21,809 tons of weldless tubes, and 14,700 tons of plates. The average production per blast-furnace was 15·47 tons per day. Charcoal was the sole fuel used, the consumption being 43,468,603 hectolitres.

The export of iron ore from Sweden in 1905 amounted to 3,316,127 tons, and that of pig iron to 110,217 tons.†

The Swedish production during the first half of 1906 is said to have comprised 308,100 tons of pig iron, 87,700 tons of castings, 41,400 tons of Bessemer ingots, and 145,200 tons of open-hearth ingots. There were in operation 116 blast-furnaces, 258 hearths, 19 Bessemer converters, and 52 open-hearth furnaces.‡

XXI.—*TURKEY.*

Mineral Resources.—B. Simmersbach § discusses the economic development of some of the Turkish mining districts.

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* *Kommerskollegii Underdaniga Berättelse*, Stockholm, 1906.

† *Affärsvärlden*, May 25, 1906.

‡ *Ibid.*, September 6, 1906.

§ *Verhandlungen des Vereines zur Beförderung des Gewerbfleisses*, vol. lxxxiv. pp. 487-501.

XXII.—*UNITED STATES.*

Mineral Statistics.—According to W. R. Ingalls,* the United States in 1905 produced 44,578,456 tons of iron ore, 47,991 tons of bauxite, 50,340 tons of fluorspar, 4,260,656 lbs. of graphite, 14,098,000 tons of limestone flux, 6 tons of molybdenum ore, 834 tons of tungsten ore, and 352,694,110 tons † of coal.

Iron Trade Statistics.—According to statistics collected by J. M. Swank,‡ the total production of pig iron in the United States in 1905 was 22,992,380 tons. The total production of open-hearth steel ingots and direct castings in the United States in 1905 was 8,971,376 tons, against 5,908,166 tons in 1904, an increase of 3,063,210 tons, or over 51·8 per cent. 7,815,728 tons were made by the basic process, and 1,155,648 tons by the acid process. The production of open-hearth steel ingots in 1905, excluding castings, amounted to 8,444,836 tons, against 5,605,332 tons in 1904. The production of open-hearth steel castings in 1905 amounted to 526,540 tons, of which 206,159 tons were made by the basic process and 320,381 tons by the acid process. Bessemer steel ingots and castings 10,941,375 tons, structural shapes, not including plates, 1,660,519 tons, and iron and steel wire rods 1,808,688 tons, and Bessemer steel rails 3,192,347 tons, were produced.

The iron industry of the United States is described by B. Osann.§

The birth and growth of the economic development of the American steel industry is reviewed by J. N. Hatch.‖

Iron Ore.—The year 1905 stands pre-eminent in production of iron ore with a total, according to John Birkinbine,¶ of 42,526,133 tons for the United States. As compared with 1904 the increase was 54 per cent.

The region which still takes the lead in the annual output is that of Lake Superior, which produced in the year 1905 the large amount of 33,325,018 tons, thus exceeding its former maximum of 26,977,404 tons in 1902 by 24 per cent., and that of 1904 by 65 per cent. The five mineral ranges which compose the Lake Superior region supplied more than three-fourths of the total iron mined in the United States during 1905; the total output of the region since it was first utilised being about 300,000,000 tons. Of this amount 77,000,000 tons have been shipped from the Marquette Range, in Michigan, since 1854, and the Menominee Range, in Michigan and Wisconsin, has, since its opening in 1877, supplied 53,500,000 tons. Since 1884 the Gogebic Range, in Michigan and Wisconsin, has produced 47,000,000 tons; and the Vermilion Range, in Minnesota, also opened in 1884, has supplied 23,500,000 tons. All these are worthy of note; but the most remarkable shipments have been from the Mesabi Range, in Minnesota, which, since 1892, have amounted to a total of 99,000,000 tons, or nearly one-third of the ore obtained from the Lake Superior region.

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* *Mineral Industry*, New York, vol. xiv. pp. 4-5.

† Metric tons.

‡ *Annual Statistical Report of the American Iron and Steel Association*, 1905, p. 17.

§ *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. liv. pp. 198-221.

‖ *Journal of the Western Society of Engineers*, August 1906.

¶ *Mineral Resources of the United States*. Advance chapter. Washington, 1906.

G. Rivière,* in an exhaustive discussion of the metallurgical and mining developments of the United States, deals with the iron ore supplies of various districts, and gives statistics as to the outputs, analyses of the composition of the ores mined, and descriptions of the methods of mining and modes of transport employed.

Coal.—E. W. Parker † gives the production of coal in the United States.

Manganese Ore.—According to John Birkinbine,‡ the production of manganese ore in the United States in 1905 amounted to 4118 tons, with 769,256 tons of manganiferous iron ore, and 81,738 tons of argentiferous manganiferous iron ore.

Coke.—E. W. Parker § gives statistics showing the output of coke in the United States.

E. A. Ritter ‖ gives some particulars as to the production of coke in the coalfields of the Rocky Mountains. In 1899 the number of works in the four districts he discusses—Colorado and Utah, Montana, New Mexico, and Washington—was 19, the total number of ovens was 1762 and the amount of coal used was 1,225,900 tons, whereas in 1904 there were 27 works with 4329 ovens, using 1,521,650 tons of coal, the average yield of coke being 59 per cent.

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* *Bulletin de la Société des Ingénieurs Civils*, 1906, No. I. pp. 317–345.

† *Mining World*, vol. xxv. p. 372.

‡ *Mineral Resources of the United States.* Advance chapter. Washington, 1906.

§ *Mining World*, vol. xxv. p. 238.

‖ *Annales des Mines*, vol. x. p. 80.

Steel-Hardening Metals.—Under the head of steel-hardening metals are included all the metals that are used for steel-hardening purposes—these are nickel, chromium, manganese, tungsten, molybdenum, vanadium, titanium, cobalt, and uranium. The production of these metals in the United States in 1905, except manganese, was 922 tons as compared with 1004 tons in 1904, a decrease of 82 tons.[*]

Natural Gas.—According to the annual report of the United States Geological Survey[†] the value of the natural gas produced in 1905 was £8,312,571.

Tinplates.—Statistical details regarding the production of tinplates in the United States have been published.[‡]

Carborundum.—The production of carborundum in the United States during 1905 is returned[§] at 5,596,000 pounds, as compared with 7,060,380 pounds in 1904. The most refractory variety is infusible at 7000° F. and unaffected by oxygen, ozone, or sulphur at 3000° F.

Metallurgical Education.—An illustrated description has appeared[||] of the new buildings of the Columbia University devoted to the teaching of mining and metallurgy. The laboratories are furnished with every appliance for metallurgical work, and are equipped with apparatus for studying the structure of metals, alloys, and slags.

The gas-engine plant of the Carnegie Technical Schools, Pittsburg, Pennsylvania, is described[¶] and illustrated. It consists of a 500 horse-power gas-engine made by the Westinghouse Machine Company.

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[*] *Bulletin of the American Iron and Steel Association*, vol. xl. p. 125.

[†] *Bradstreets*, vol. xxxiv. p. 703.

[‡] *Bihang till Jernkontorets Annaler*, 1906, pp. 415–416.

[§] *United States Geological Survey*, 1905. (Advance proof.)

[||] *Iron Trade Review*, April 19, 1906, pp. 26–27.

[¶] *Iron Age*, vol. lxxvii. pp. 1601–1604, with four illustrations.

XXIII.—*COMPARATIVE TABLES.*

The World's Production of Coal and Iron.—For purposes of comparison the following summary of the production of coal in the principal countries of the world is appended:—

Country.	Year.	Production in Tons.
United Kingdom	1905	236,128,936
Australasia—		
New South Wales	1905	6,632,138
New Zealand	1905	1,585,756
Queensland	1905	529,326
Tasmania	1905	51,993
Victoria	1905	155,135
Western Australia	1905	127,364
Austria, coal	1905	12,585,263
,, lignite	1905	22,692,076
Hungary, coal	1905	1,088,086
,, lignite	1905	6,088,577
Belgium	1905	21,775,280
Bosnia	1905	540,237
Bulgaria	1904	142,315
Canada	1904	7,509,860
Cape Colony	1904	154,272
Chili	1903	827,112
France	1905	35,869,497
Germany, coal	1905	121,298,167
,, lignite	1905	52,498,507
Greece, lignite	1904	10,000
Holland	1904	466,997
India	1905	8,417,739
Italy, coal and lignite	1905	412,916
Japan	1903	10,088,845
Mexico	1904	700,000
Natal	1905	1,129,407
Peru	1905	72,665
Portugal, anthracite	1904	12,805
Roumania, lignite	1903	110,000
Russia	1904	19,318,000
Servia	1904	183,204
Spain	1905	3,202,911
Sumatra	1904	207,280
Sweden	1905	322,384
Transvaal	1904	2,409,033
Turkey	1903	300,000
United States	1905	350,821,000

The production of coal in 1905 in the United Kingdom, Germany, France, the United States, and India was greater than in any previous year. In the United Kingdom the production of coal amounts to 5½ tons per head of population, in the United States to 4½ tons, in Belgium to 3 tons, in Germany to 2 tons, and in France to 1 ton.

A similar summary showing the production of pig iron is as follows:—

Country.	Year.	Production in Tons.
United Kingdom	1905	9,608,086
Austria	1905	1,119,614
Hungary	1905	421,282
Belgium	1905	1,310,290
Bosnia	1905	43,074
Canada	1905	403,449
France	1905	3,076,550
Germany and Luxemburg . . .	1905	10,875,061
Italy	1905	143,079
Japan	1904	34,000
Russia	1905	2,715,063
Spain	1905	383,100
Sweden	1905	539,437
United States	1905	23,360,258

B. Neumann [*] reviews the progress made in the metallurgy of iron in 1905. The world's production of pig iron that year amounted to 54,060,783 tons. The world's production of steel in 1905 was 43,753,555 tons, of which the United States produced 20,231,352 tons, Germany 10,066,553 tons, and Great Britain 5,941,344 tons.

Comparative statistics of the world's coal production in 1905 have been issued. [†]

Comparative Mineral Statistics.—The British Home Office has issued a report [‡] on statistics relating to persons employed, output, and accidents at mines and quarries in the British colonies and in foreign countries in 1904. The number of persons employed at home and abroad was about five millions, of which one-fifth were employed in the United Kingdom and one-third in the British Empire. More than half of the total were employed in getting coal, of which the world's production was 886 million tons, valued at 295 million pounds sterling. In coal-mines the death-rate from accidents per 1000 employed was 1·24 in the United Kingdom, 1·24 in the British Empire, 1·90 in Germany, and 3·35 in the United States.

C. K. Leith [§] considers that in published estimates of iron ore reserves, low grade ore is not sufficiently considered.

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[*] *Glückauf*, vol. xlii. pp. 879–889; *Chemische Zeitschrift*, vol. v. pp. 421–422.

[†] *Coal Tables*, Parliamentary Paper 321, 1906.

[‡] Cd. 2911. Price 1s. 9d.

[§] *Canadian Mining Review*, vol. xxvi. pp. 181–183.

The World's Production of Manganese.—J. Birkinbine[*] gives the following figures as the latest statistics available for the world's production of manganese ore:—

Country.	Year.	Quantity.
North America—		Tons.
United States	1905	4,118
Canada †	1905	22
Cuba †	1905	6,907
South America—		
Brazil †	1905	233,950
Chile †	1903	17,110
Europe—		
Austria	1905	13,788
Bosnia and Herzegovina	1905	4,129
Hungary	1904	11,527
France	1904	11,254
Germany	1904	52,886
Greece	1904	7,355
Italy	1904	2,836
Portugal	1903	30
Russia	1905	426,813
Spain	1904	26,895
Sweden	1905	1,992
Turkey †	1904	49,100
Norway	1904	22
Asia—		
India	1904	150,297
Japan	1902	10,592
Java	1899	1,388
Oceania—		
Queensland	1904	830
New Zealand	1904	196

C. Dantin ‡ describes the principal deposits of manganese ore in the world and estimates the available supply.

The World's Production of Petroleum.—Details are given of the world's production of petroleum in 1905, the total being estimated to be 28,248,213 tons.§

Comparative Exports of Iron and Steel.—Details are given ‖ for each of the years 1900–1905 relating to the totals and main items of the iron and steel exports from Germany, the United Kingdom, the United States, and Belgium. For the year 1905 these showed that the United Kingdom exported about 120,000 tons less finished or part finished material than Germany, but that including pig iron its exports exceeded those of Germany by 510,000 tons, and were nearly four times as much as the United States or Belgium.

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[*] "Production of Manganese Ores in 1905." Washington, 1906.

† Exports.

‡ *Génie Civil*, vol. xlviii. pp. 343–345.

§ *Moniteur du Pétrole Roumain*, vol. vii. pp. 297–298.

‖ *Stahl und Eisen*, vol. xxvi. pp. 622–625.

The World's Railways.—Details are given * as to the length of the world's railways at the close of 1904, the progress made in that year, and the new developments in progress.

The jubilee of the Swedish State Railway has been celebrated, the first section having been opened on December 1, 1856.† At the end of 1905 the total length of railways in Sweden was 12,670 kilometres. This represents a proportion per head of population far in excess of any other country.

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* *Archiv für Eisenbahnwesen*, 1906, No. 3.

† *Affärsvärlden*, vol. vi. p. 1403.

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[Part I. dealing with hot saws.]

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[A treatise on moulding in iron foundry practice.]

WEDDING, H. "*Grundriss der Eisenhüttenkunde.*" 5th edition. 8vo, pp. 392, with 205 illustrations in the text and 2 plates. Berlin: W. Ernst & Son. (Price 9s.)

[The fifth edition of this standard introduction to iron metallurgy has been revised throughout. It deals with the metallurgical chemistry and physics of iron, pig iron production, wrought iron and steel production, the further treatment of iron, and the history of iron.]

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[Gives, in the form of questions and answers, a brief discussion of the types of apparatus and the methods used in the manufacture of producer-gas; together with an outline of its history, its present and future uses, and its advantages.]

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"*Becker's Taschenbuch für Kohlen-Interressenten.*" 6th annual issue. 8vo. Teplitz. (Price 3s.)

[Contains a list of the collieries in Austria, and a map of the Bohemian brown-coal district.]

BAEDEKER, C. D. "*Tafeln zur schnellen Bestimmung der wichtigsten Verhältnisse beim Berechnen von Ventilatoranlagen für Bergwerke zum Gebrauche fur technische Grubenbeamte, Ingenieure und Fabrikanten.* 2nd edition. Essen. (Price 3s.)

BALLING, C. "*Die Schätzung von Bergbauen und Eisenbahnschutzpfeilern.*" 2nd edition. 8vo, with 3 plates. Teplitz: A. Becker. (Price 7s.)

BEYLING. "*Versuch zwecks Erprobung der Schlagwettersicherheit besonders geschutzter elektrischer Motoren und Apparate.*" 4to, pp. 89, with 137 illustrations. Essen: *Glückauf.* (Price 2s. 6d.)

[The tests described were made at Gelsenkirchen, and show that electric machinery for collieries should be constructed with the greatest possible care to obviate sparking as far as possible, and that such motors should be enclosed in suitable casings strongly made.]

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[Deals with Prussian coal-mines from the point of view of the political economist.]

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BRATHUHN, O. "*Handbuch der Markscheidekunst.*" 2nd edition. 8vo, with 190 illustrations. Leipzig: J. J. Weber.

[An elementary treatise on mine surveying by the professor at the Clausthal School of Mines.]

BROUGH, BENNETT H. "*A Treatise on Mine Surveying.*" 12th edition, revised. 8vo, pp. 372, with 102 illustrations. London: Charles Griffin & Co., Limited. (Price 7s. 6d.)

BULMAN, H. F., and R. A. S. REDMAYNE. "*Colliery Working and Management.*" 2nd edition. 8vo, pp. 418, with 28 plates and 129 illustrations.

[The original text has been revised, and new matter to the extent of 100 pages has been added. The additions include a chapter by R. M. Johns on the colliery manager and the law.]

CARBONELL, J. "*Tratado de legislacion de minas.*" 4to. Salamanca. (Price 17 francs.)

CLARK, W. B. "*Coals of Maryland.*" 4to, pp. 651, illustrated. Baltimore: Maryland Geological Survey. (Price 15s.)

COLOMER, F. "*Recherches Minières.*" 2nd edition. 8vo, pp. 312, with 122 122 illustrations. Paris: Dunod. (Price 8½ francs.)

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COLOMER, F., and C. LORDIER. "*Combustibles Industriels.*" 2nd edition. 8vo, pp. 568, with 185 illustrations. Paris: Dunod. (Price 18 francs.)

COPPERTHWAITE, W. C. "*Tunnel Shields and the Use of Compressed Air in Subaqueous Works.*" 4to, pp. 39, with 260 illustrations. London: Archibald Constable & Co. (Price 31s. 6d.)

COX, S. H. "*Prospecting for Minerals.*" 4th edition. 8vo. London: Charles Griffin & Co., Limited. (Price 5s.)

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ESCARD, J. "*Le carbone et son industrie.*" 8vo, pp. 784, with 129 illustrations. Paris: Dunod. (Price 25 francs.)

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GAUTIER, FERDINAND. "*Chili et Bolivie, étude economique et minière.*" 8vo, pp. 229. Paris: E. Guilmoto. (Price 6 francs.)

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"*Handbuch der Ingenieurwissenschaften.*" No. 2. 8vo, pp. 431, with 14 plates and 270 illustrations. (Price 16s.) No. 5. 8vo, pp. 427, with 3 plates and 269 illustrations. (Price 12s.) Leipzig: W. Engelmann.

HARTMANN, K., and J. O. KNOKE. "*Die Pumpen.*" 3rd edition, revised by H. Berg. 8vo, pp. 636, with 704 illustrations and 14 plates. Berlin: J. Springer. (Price 18s.)

HASSEL, T. "*Der Internationale Steinkohlenhandel.*" 8vo. Essen: G. D. Baedeker. (Price 6s.)

HENRY, J. D. "*Baku.*" 8vo, illustrated. London: Archibald Constable & Co., Limited. (Price 12s. 6d. net.)

[Describes the origin, progress, and present position of the Russian petroleum industry.]

HICKS, J. A. "*The Laboratory Book of Mineral Oil Testing.*" With introduction by Sir Boverton Redwood. sm. 8vo, pp. 68, with 31 illustrations. London: C. Griffin & Co., Limited. (Price 2s. 6d net.)

HIRSCH, M. "*Die Luftpumpen. Projektierung, Berechnung und Untersuchung der Kompressoren und Vakuumpumpen.*" 8vo. Hanover: M. Jänecke. (Price 8s.)

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LAUS, H. "*Die nutzbaren Mineralien und Gesteine der Markgrafschaft Mähren.*" 8vo, pp. 182, with geological map. Brünn: C. Winiker.

LEMIÈRE, L. "*Formation et recherche comparées des divers combustibles fossiles.*" 8vo, with 21 illustrations and 6 plates. (Price 7½ francs.)

MELLIN, R. "*Der Steinkohlenbergbau des preussischen Staates in der Umgebung von Saarbrücken.*" Part III. 8vo, pp. 336, with 53 illustrations and 14 plates. Berlin: J. Springer.

[Deals with mining engineering at the Saarbrücken collieries. The other five volumes of the work were published in 1904.]

NEUMANN, F. "*Die Zentrifugalpumpen.*" 8vo, pp. 205, with 135 illustrations and 7 plates. Berlin: J. Springer. (Price 8s.)

Pantz, A von. "*Die Innerberger Hauptgewerkschaft*, 1625–1783." 8vo, pp. 179, with 1 plate. Graz. (Price 3s. 6d.)

[A careful historical review of an ancient iron-making district of Inner Austria, the result of five years' careful search of Imperial and local archives. The plate gives a reproduction of a view of the Styrian iron ore mountain in the year 1649.]

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[Contents.—Introductory—Classification of Mineral Deposits—Ore Veins, their Filling, Age, Structure, Wall Movements, Pay-shoots, &c.—The Dynamics of Lodes and Beds—Ore Deposits Genetically Considered—Theories of Vein Formation—Ores and Minerals considered Economically—Mine Sampling and Ore Valuation—The Examination and Valuation of Mines—Index.]

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